discovered

THE HZDR RESEARCH MAGAZINE

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The Hunt for Raw Materials

When magnets become frustrated
HZDR physicists investigate strange quantum phenomena

Germany’s hidden treasures
Tracking down indigenous resources

Color lies in the beholder’s ... gender
New insights into perception

HZDR
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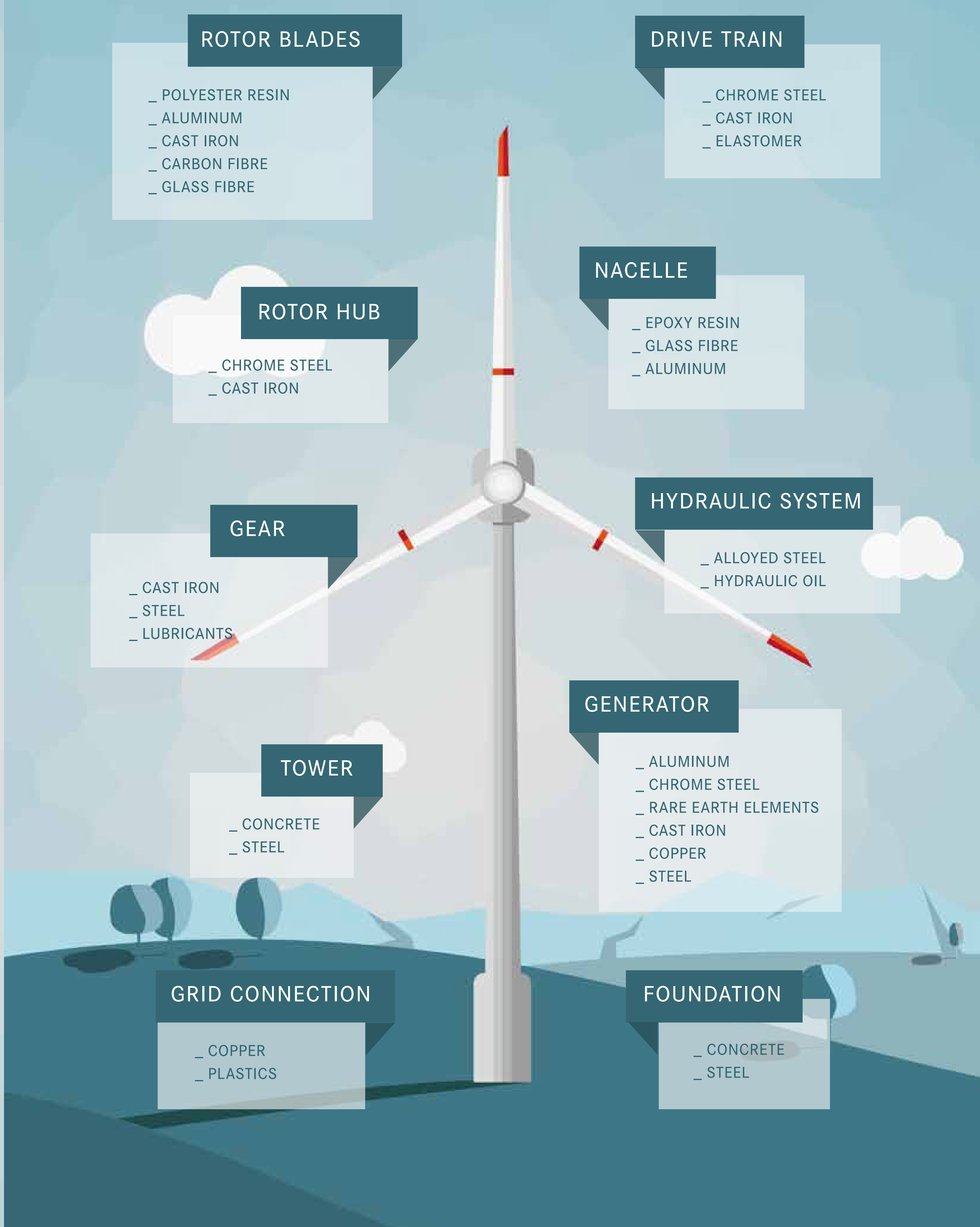
The cost of the wind

We are dependent on raw materials: in our everyday lives, a whole raft of different metals – hidden away in our smartphones and computers – ensure, for example, that we can enjoy the convenience of modern methods of communication. In terms of society as a whole, the relevance of resources is also hard to overestimate. Especially the long-term switchover from fossil fuels and nuclear energy sources to renewables is causing our need for base metals like iron, copper and aluminum to skyrocket. Just think of a typical wind farm: that consumes more than 200 tons of metal. Experts at French universities have calculated that 1.15 tons of copper, 3 tons of aluminum and 130 tons of ferrous metals are required to produce one megawatt of wind power. On top of which come numerous rare earths like neodymium and molybdenum.

Thanks to years of cheap raw material imports, in the last 20 years, German industry has very largely relied on sourcing the necessary resources abroad. Rising prices and scarcity on international markets have, however, shown what this means in terms of dependency, which in the worst case can bring production grinding to a halt. Part of the solution may lie in the German soil which is not really as short on raw materials as popular myth would have us believe. It just has not been explored sufficiently. Researchers at the Helmholtz-Zentrum Dresden-Rossendorf are thus developing new, environmentally-friendly methods of tracking down hidden treasures. But even the existing treatment processes and recycling could be much improved, they believe. In this context, recovering resources could play an ever more important role in the future.

Wind farms may then very well not just deliver energy from renewable sources but – at the end of their lifespan – even provide the foundations for the next generation of power plants.



According to T. Zimmermann et al., in Resources, 2013 (DOI: 10.3390/resources2030303)

Source: A. Wirsig

Dear readers,

There are riches to be found lurking in my desk drawer: four old cell phones, two discarded laptops and an antiquated digital camera or, if we were to take the devices apart, gold, silver, other metals and rare earths. If we consider the number of drawers in Germany that can boast similar contents, the result is a mass of raw materials that could well be used for something else. Disposal experts estimate, for example, that every year, more copper ends up in the garbage in Germany than is produced by the largest Chilean copper mine.

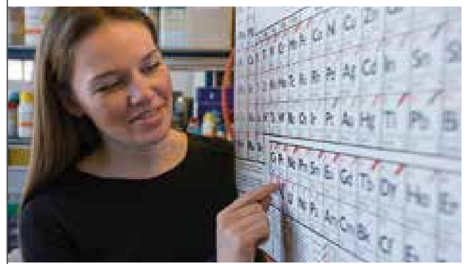
The problem is that only extremely small amounts of valuable or "exotic" metals like palladium or tantalum are built into the devices and it is exceedingly complicated to recover them. If this is going to change, manufacturers will have to consider the ultimate demise of their equipment at the very beginning of the production chain. It is just this kind of strategy, which could facilitate a circular economy, that scientists at our Helmholtz Institute Freiberg for Resource Technology are developing. But recycling is not the only thing occupying our researchers – they are also investigating environmentally-friendly exploration and efficient raw materials processing.

While all this is going on, engineers are working on economical and reliable technologies for storing energy from fluctuating sources such as sun and wind, while physicists have set themselves the goal of curbing the enormous power appetite of modern electrical appliances. This and similar interdisciplinary research on the pressing energy issues of our time is what we would like to present to you in this new edition of our magazine "discovered".

I look forward to receiving your questions, comments and suggestions and wish you all happy reading.

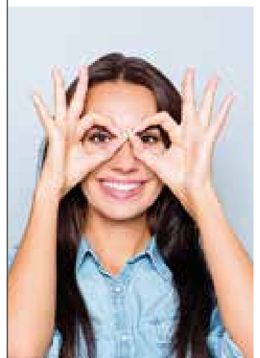
Simon Schmitt
Chief Editor

Content



Cover Picture: Many of our everyday electronic appliances contain a wealth of raw materials. How these resources can be recovered and re-used at the end of the devices' lifespan is a focus of researchers at the Helmholtz-Zentrum Dresden-Rossendorf. Source: Juniks

Portrait



Research

Title

The Hunt for Raw Materials

Panorama

Research Highlights

RADIATION ONCOLOGY

How far do all the protons go?

For protons to hit a tumor with great accuracy, clinicians must know how far the beams enter the body. Together with colleagues from the German Cancer Research Center, OncoRay scientists have now developed and comprehensively validated a new calculation method that allows far more accurate range measurements. The new method is based on dual-energy computer tomography (DECT) which generates two CT images with different X-ray energy spectra. Scientists used the new algorithm to analyze DECT images of 50 patients with brain or prostate tumors to show that previously used methods resulted in clinically relevant deviations between planned and actual range. Dresden proton therapy center is thus the first institution in the world to use information from DECT calculations to enhance the accuracy of the standard method. In 2018, the researchers want to switch entirely to DECT-based calculations.

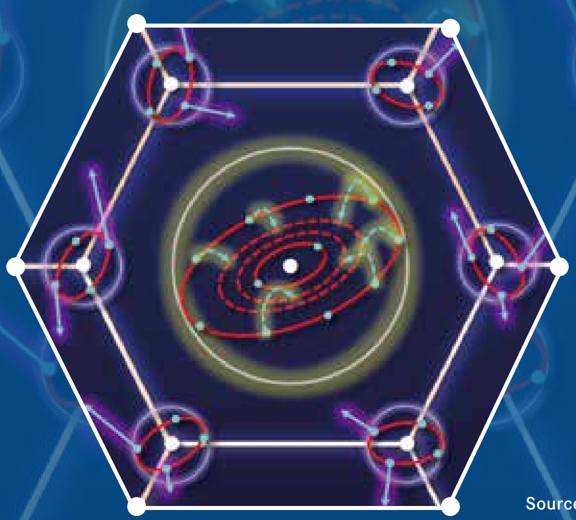
Publication:
P. Wohlfahrt et al., in Radiotherapy and Oncology, 2017
(DOI: 10.1016/j.radonc.2017.09.042)

ATOMIC PHYSICS

Hollow, but powerful

Researchers at TU Wien and HZDR were able to show why highly excited electrons of so-called “hollow atoms” release almost their entire energy upon ultra-short contact (femtoseconds) with solids. This phenomenon is caused by an effect that has previously gathered little attention in this context: the Interatomic Coulombic Decay. It involves an electron transferring its energy to several other electrons of neighboring atoms when the hollow atom impacts the surface. In their experiments, physicists transmitted xenon ions through a graphene layer, where they interact with several carbon atoms. This causes at first electron capture from the graphene. Then, these captured electrons release their high energy, by exciting multiple electrons in the graphene forcing them to leave their normal position and fly away – though each at relatively low energies.

Publication:
R.A. Wilhelm et al., in Physical Review Letters, 2017
(DOI: PhysRevLett.119.103401)



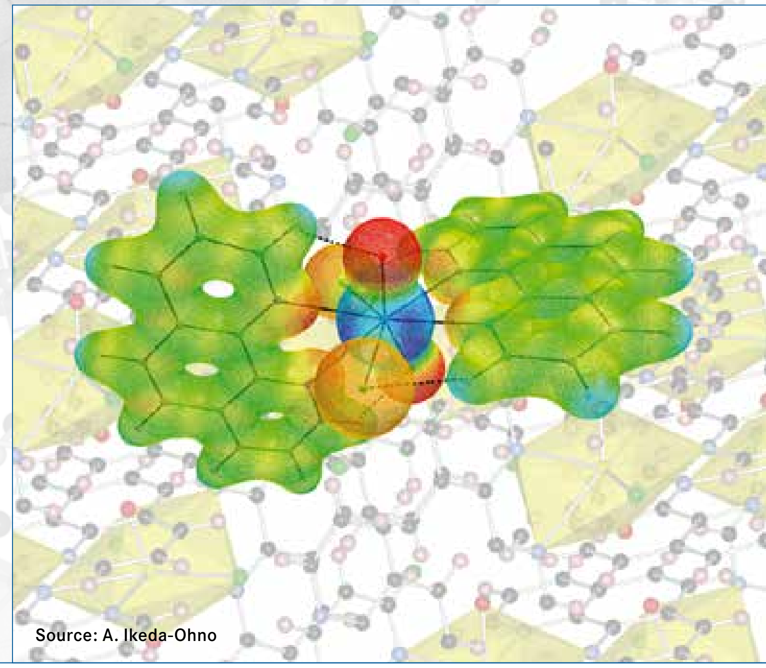
Source: TU Wien

RESOURCE ECOLOGY

Bent out of shape

Radiochemists at HZDR have successfully produced a uranyl compound with a unique geometry. Normally, such complexes involve a compound of two oxygen atoms and one uranium atom, creating a linear and very stable unit at a 180-degree angle. The new substance, however, features a significantly bent angle of 161.8 degrees – one of the smallest angles ever demonstrated for this unit. At the same time, two nitrogen-containing molecules as well as two chlorine atoms attach themselves to this unit so that a coordination polyhedron consisting of twelve triangles (dodecadeltahedron or snub disphenoid) is created. This unusual structure can potentially enhance the substance’s chemical reactivity.

Publication:
S. Schöne et al., in Chemistry – A European Journal, 2017
(DOI: 10.1002/chem.201703009)



Source: A. Ikeda-Ohno

TUMOR IMMUNOLOGY

A bridge for the immune system

Scientists at HZDR’s Institute of Radiopharmaceutical Cancer Research and Dresden University Hospital are working on a new, genetically engineered drug to combat a particularly aggressive form of leukemia. The preparation is based on the specially designed protein “GEM333”. One end of this protein is supposed to dock onto specific immune cells, called T-cells, inside the patient while the other end will attach itself to the cancer cells. Toxins can then travel over this bridge from the immune cell into the leukemia cell and destroy it. After 15 years of research – a comparatively short span of time – the drug now meets all the requirements for first use in humans. In early 2018, 35 patients in Dresden and Würzburg will be treated with the substance.

Publication:
R. Aliperta et al., in Scientific Reports, 2017
(DOI: 10.1038/srep42855)

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giga watt hours of electrical power are every year consumed by Germany’s local sewage treatment plants – roughly the annual output of a modern coal-fired power plant. The most energy-hungry processes in waste water treatment occur in the aeration tanks, where bacteria reduce carbon and ammonia compounds with the help of added oxygen. Most sewage plants, however, actually use more energy than they need because they are not optimally designed. So far, they have lacked the appropriate measuring and simulation methods to understand the complex processes in the tanks. Scientists from HZDR’s Institute of Fluid Dynamics collaborated with colleagues from TU Dortmund and the Institute for Water and Energy Bochum to build models that effectively predict flow behaviors, which will help them develop better mixing and aeration strategies.

Publication:
A.E. Sommer et al., in Flow Measurement and Instrumentation, 2017 (DOI: 10.1016/j.flowmeasinst.2016.05.008) – with support from the German Federal Environmental Foundation (AZ30799)

Source: HadelProductions / istock

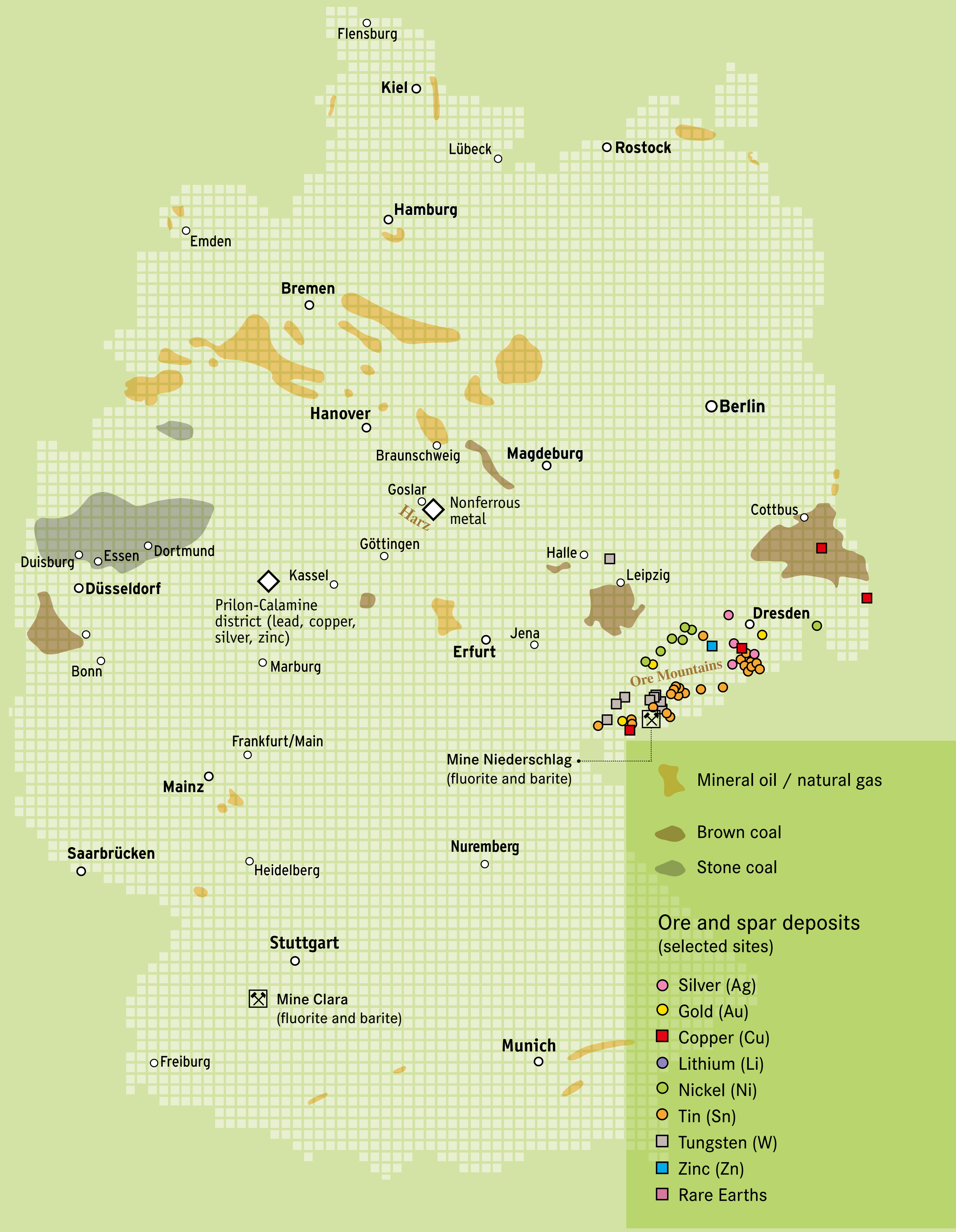
Germany's hidden treasures

The *Energiewende* is systemically changing our use of raw materials. While the need for coal, oil and gas is decreasing in the long term, the demand for metals and construction materials for energy-efficient wind and solar plants, battery and hydrogen storage or other systems is growing. Germany is not yet fully exploiting its potential in this field.

_ Text . Marcus Schick

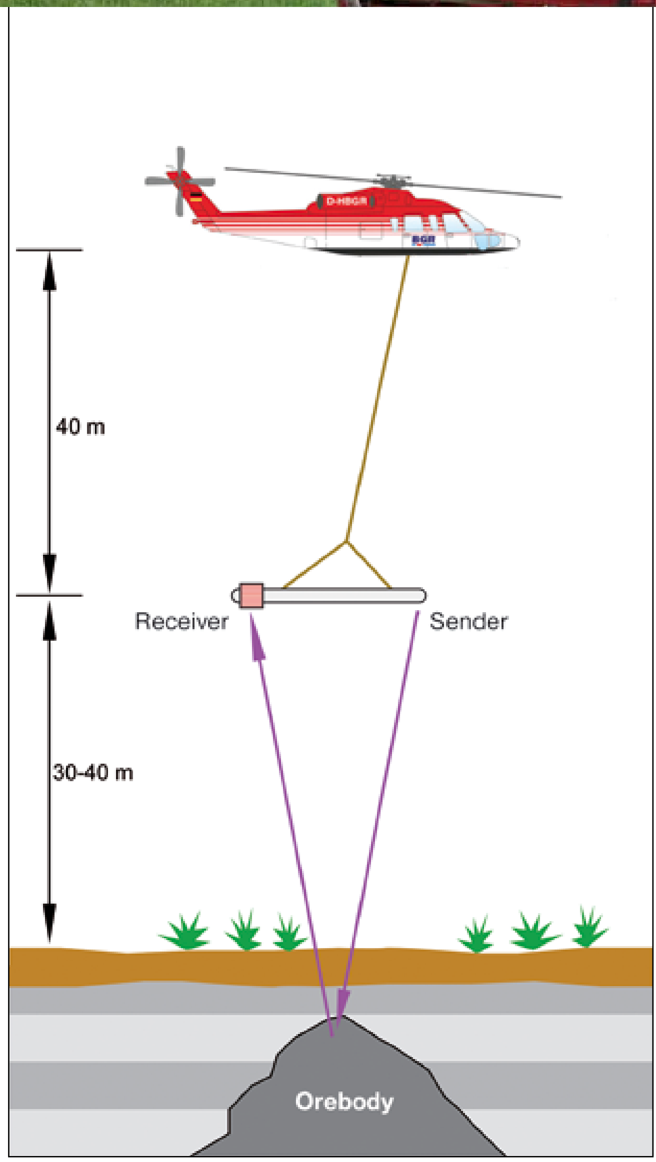
This article is heavy, because it is written on a computer. According to estimates from the Wuppertal Institute and a UN study, some 19,000 kilos of raw materials, including the fuels that go into power generation, are needed to manufacture a single computer. Apart from 1,500 liters of water, 22 kilos of chemicals and 240 kilos of fossil fuels are required. But what really determines computing power are precious and technology metals, particularly copper, tin, gold, tantalum and many others from all over the world. And because a lot of calls had to be made before this article could be written, one should really include land line and cell phones on the raw materials balance sheet as well.

But enough playing around with numbers. What is clear is that raw materials are an omnipresent and indispensable part of our lives – because they are not just found in computers and phones but at the heart of every kind of technology and electronics. Raw materials are part of the DNA of technological progress. There is no alternative to them yet, and their availability is limited. This is precisely the dilemma >



Source: F.A.Z.-Grafik / Christine Sieber; revised by Helmholtz-Zentrum Dresden-Rossendorf

Non-invasive exploration in the outdoors: In the Saxony "Ore Mountains", HIF scientists search for raw materials using a helicopter equipped with a sensor that can transmit and receive signals. The information they gather about sub-surface electrical conductivity indicates the possible presence of ore bodies. Source: VNG / D. Müller (above)



facing industrial nations. Since Germany has committed to the *Energiewende*, it will need to increasingly cover its demand for energy with wind and solar power plants. But without raw materials, renewables will not be working. Admittedly, renewables reduce the long-term demand for coal, oil and gas, but at the same time, the need for inorganic raw materials increases. They are essential for producing the plants that generate power from renewables and that store the energy.

"In the new energy technologies, we largely use the same raw materials as we do for other high-tech products," explains Jens Gutzmer, Director at the Helmholtz Institute Freiberg for Resource Technology (HIF), which is affiliated to the Helmholtz-Zentrum Dresden-Rossendorf. These include, above all, technology metals like copper, cobalt, platinum group metals, but also specialty metals such as indium, tellurium, gallium and germanium, or rare-earth elements. According to Gutzmer, they are just as essential for the energy sector as for the automotive industry or the electronics, information and communication branches. "Because Germany has essentially no mining industry of its own and the recycling rates for raw materials like rare-earth elements or indium, tellurium, gallium and germanium are very low, Germany is dependent to a very high degree on imports of metalliferous raw materials and intermediates."

A focus on critical raw materials

Given this diagnosis, politicians have identified the sustainable supply of raw material as an essential task for the industry. The German government has created the necessary framework for the industry with its raw materials strategy. Within the context of this strategy the government seeks to introduce a plethora of measures to improve access to raw materials in a global market that is both transparent and fair. Other actions include the support of research into raw materials and substitution, as well as transparency and good governance in raw materials production. These national measures dovetail with European raw materials policy. New structural measures have also been introduced like the establishment of the German Mineral Resources Agency (DERA) at the Federal Institute for Geosciences and Natural Resources, the foundation of the Helmholtz Institute in Freiberg and the introduction of an Inter-Ministerial Committee on raw materials.

Industry, in particular small and medium-sized enterprises, is designated as the beneficiary of this knowledge and consultancy support. By monitoring critical resources, information on supply and demand trends for mineral raw materials is made available to help identify, well in advance, delivery risks or unwanted developments on the raw materials markets. All these measures are always interlinked with the government's activities at European level.

Energiewende at the crossroads

Only time will show how the demand for raw materials will develop in practice. Experts from the German National Academy of Sciences Leopoldina, the National Academy of Science and Engineering, acatech, and the Union of German Academies of Science recently investigated whether the success of the *Energiewende* might in the end be endangered by a lack of raw materials. In the project "Energy Systems of the Future", some 100 researchers worked in interdisciplinary groups on ways of progressing to an environmentally benign, secure and affordable energy supply.

And the good news is: it is possible to secure sufficient supplies of metals, fossil fuels and bioenergy for the *Energiewende* in Germany. Globally, there are sufficient raw material resources known to satisfy demand for the foreseeable future. The urgent question is thus not whether supply can be guaranteed in general but how it can be achieved. Prices, for example, are decisive and the math is fairly simple: If the metals get too expensive, investing in more climate-friendly technologies makes less economic sense. But another question is just as important: whether and how the required expansion of the mining industry – an industry often viewed with suspicion regarding its impact on the environment – will find social acceptance. "Germany needs a long-term raw materials policy," the authors of the study claim, "in order to promote open, transparent markets and high environmental and social standards. More recycling and mining in Germany, Europe and the deep sea as well as strategic investment in raw materials projects can improve the security of supply."

While Germany has no alternative but to import metalliferous raw materials, it is self-sufficient when it comes to construction raw materials like sand and gravel and certain industrial minerals such as kaolin and gypsum. The only limits stem from competing interests such as environmental or potable water resource protection.

Harnessing geopotentials

The experts base their assessment of geological availability on the reserves that have already been tapped, the resources – that is, the raw material volumes that are known but currently not exploitable with today's technology and at today's prices – and the geopotentials. The latter refer to volumes of raw materials that may be present in certain geological structures, for example, but have not yet been identified by actual exploration. "By exploring, continuing to develop mining, and processing technologies and with increasing market prices, geopotentials and resources can be transformed into reserves," Jens Gutzmer explains. This means that the reserves of most raw materials actually "grow" with use, sometimes disproportionately in terms of consumption. Take oil, for example: From 1950 to 2013, consumption increased eightfold while the reserves went up twentyfold thanks to new methods of exploration and exploitation technologies.

Whether this can happen with mineral resources as well? It would be good if it could. A current risk analysis by DERA on lithium, for example, shows that demand for this alkali metal, which is crucial for state-of-the-art batteries, could triple by 2025. If electromobility would now really take off – decisively driven by high, state-imposed quotas in China – the DERA experts reckon that total demand for cobalt could more than double in this period, too. And the world boom in battery production would also have a significant impact on the graphite market. Why? Because graphite is an essential component for the anodes of lithium-ion batteries both in a synthetic form and as natural spheroidal graphite. Approximately 1.1 kilos of graphite are needed per kilowatt hour of battery capacity in modern electric cars. Industry requires lithium and cobalt first and foremost as material for the cathodes.

Circular economy: mining electronic waste

Particularly in Germany, the requirements for electromobility and the implementation of the *Energiewende* focus attention not only on primary raw material production through mining but also on the utilization of so-called "secondary deposits". In an increasingly circular economy, raw materials that can be salvaged from old devices and infrastructure have long played an important role. On the supply side, this can be a response to demand-based shortages. In general, it can be observed that scarcity and price increases usually lead to more efficient and economical use or – where appropriate – to substitution by another, equally, or perhaps even more, suitable raw material. "In the last hundred years, this loop system has meant that, on average, the real prices for most raw materials have hardly increased," Gutzmer notes.

Above and beyond exploiting these secondary deposits researchers are called upon to drive technological progress in order to create the preconditions for discovering new ore deposits. "But in Germany mineral exploration doesn't play much of a role at present," is the assessment of Richard Gloaguen, head of the Exploration Division at HIF. "On the one hand, this is due to a general misconception that there are not many ore deposits in Germany and, on the other, there is a lack of political and social acceptance for mining." Critical minerals that are systemically relevant for certain industries in the energy and IT sectors, he notes, largely come from abroad, especially from resource-rich transition economies such as China, Brazil and South Africa, but also from developing countries like the Democratic Republic of Congo.

Forgotten natural resources

Different to common public perception, Germany has significant mineral resource potential. There is, for example, the rare-earths occurrence near Storkwitz in Saxony. Back in the days of the GDR, geologists discovered carbonatites enriched with light rare-earth elements and niobium, a heavy metal that is needed for specialty steels. At the time, the scientists estimated that the occurrence held about 38,000 tons of rare earths and 8,000 tons of niobium. But given that there was no interest in rare earths for smartphones or catalytic converters at the time, this potential was soon forgotten.

"In contrast to our domestic resources of copper, lithium and tin, which are a focus of interest, exploiting the Storkwitz deposits hardly makes sense economically at present time," Richard Gloaguen explains. He and his team of 20 researchers at HIF address issues such as how mineral raw material exploration can be conducted in a socially-acceptable context and which non-invasive methods can be used to minimize environmental and noise pollution at the same time.

In order to get closer to the Earth's resources, the researchers take to the air: "Using cameras and special sensors for exploration from a bird's eye view is a socially and environmentally-friendly approach," explains Gloaguen. To this end, his researchers work with a series of drones which, depending on their load-bearing capacity, are equipped with high-performance cameras and sensors. "The drones deliver the data for mapping the Earth's surface and point out

Crystal aggregates contain important metals such as indium, germanium and silver. HZDR researchers are working on innovative methods of processing them more efficiently. Source: J. Jeibmann

indicators for the presence of raw materials below ground," says Gloaguen. "The results help us to draw up the most diverse measures for developing environmentally benign exploration. Above all, we can tell people in the areas affected exactly what exploiting the raw materials will mean for them and for nature, which methods will be used and what the geologists on the spot will have to reckon with."

Research in color: the minerals' signature

Instead of turning up for exploration with diggers, pneumatic hammers and other heavy equipment, the HIF team uses so-called passive methods. The cameras and sensors on the drones capture the sun's reflection from the Earth's surface. Because minerals reflect the sunlight very differently and with their own particular characteristics, the spectrum of reflected light may be interpreted in terms of mineralogy. "Our color sensors capture far more than red, yellow and blue in all their different nuances and can thus read the signature of the respective minerals," says Richard Gloaguen, describing the procedure. Another method with the same goal is to measure magnetism and electrical resistance, which most notably differentiate iron-rich minerals from the surrounding rock.

In addition to this, the exploration researchers test laser-induced fluorescence sensors by illuminating the material from the sky with a laser beam and thus exciting fluorescence in the material. The latter depends on the absorption spectrum of the respective minerals present as well as on the properties of the laser beam and, therefore, uncovers very precise information about the material. "This is all made possible by very high-performance data processing which already exploits the potential of machine-learning and artificial intelligence," says Richard Gloaguen. "We want to use it to support the geologists' work and provide them with three-dimensional images of the areas explored. Together with them and in close cooperation with sociologists we can develop scenarios for extracting raw materials in a socially and environmentally-friendly way."

And this is something that has also caught the attention of the mining community worldwide. The European Union has assigned Richard Gloaguen's division a leading role in coordinating the recently-launched EU project INFACT (**I**nnovative **N**on-Invasive **F**ully **A**cceptable **E**xploration **T**echnologies). It is a challenging task: In the next three years, the project partners are supposed to investigate the potential of exploration that is not only highly-efficient, but also environmentally and socially benign. This will be underpinned by concrete data and experience – so that we shall still have enough raw materials in the future to go new ways in the industrial and energy sectors, for our prosperity and for the sustainable quality of life. And, last but not least, for all the computers on which future articles on research and development can be written – with the help of the sustainable use of raw materials. They don't need to be heavy, but it would be good if what they described was weighty.

With the help of drones and high-performance cameras, researchers at the Freiberg Helmholtz Institute develop new approaches of environmentally-friendly resource exploration.

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S. Jakob, R. Zimmermann, R. Gloaguen: The need for accurate geometric and radiometric corrections of drone-borne hyperspectral data for mineral exploration: MEPHySTo – A toolbox for pre-processing drone-borne hyperspectral data, Remote Sensing, 2017 (DOI: 10.3390/rs9010088)

R. Zimmermann, M. Brandmeier, L. Andreani, K. Mhopjeni, R. Gloaguen: Remote sensing exploration of Nb-Ta-LREE-enriched carbonatite (Epembe/Namibia), Remote Sensing, 2017 (DOI: 10.3390/rs8080620)

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A foam bath for ores

In nature, raw materials do seldom occur in a pure form. The valuable particles in the ores first have to be painstakingly separated from other materials and enriched. The leading method for doing this is flotation. HZDR scientists examine its underlying mechanisms and microprocesses with the aim of optimizing industrial processes and improving the extraction efficiency in raw materials processing.

_Text . Inge Gerdes

Ph.D. candidate Anna-Elisabeth Sommer studying flow processes in a flotation cell. Source: S. Floss

Froth flotation separates the valuable minerals from the gangue. Source: F. Schinski

Anything lighter than water floats towards the surface. This is the basic principle underlying material separation by froth flotation. Without it, it would be almost impossible to exploit many raw materials. "Unlike other methods, flotation is highly suited to separating fine particles," says Martin Rudolph, who heads the Division of Processing at the Helmholtz Institute Freiberg for Resource Technology (HIF). "Although ever tinier fractions of the valuable minerals are being found in the deposits."

His ten-strong research group at HIF and his HZDR-colleagues from the Institute of Fluid Dynamics are thus searching for new ways of separating even the tiniest particles and improving the resource and energy efficiency of flotation processes in industry. As around the world several billion tons are floated to extract raw materials every year, there is enormous potential for optimization. Froth flotation is not only used in processing ores but, increasingly, in material recycling.

The method utilizes the differing surface properties of mineral particles which determine to what extent gas bubbles can accumulate there. If you add gas bubbles to a fluid containing finely ground particles, the bubbles attach themselves to particles with a hydrophobic, that is, water-repellent surface. This causes upwelling and they rise to the top while the unwanted hydrophilic grains remain in the fluid phase, the slurry. On the surface of the fluid the "good" particles with bubbles attached form a layer of froth which is continually skimmed off. The rest of the particles, the so-called gangue, are pumped off at the end of the process.

How to stay dry in water

But how do you make the gas bubbles in the flotation cell collect the right particles and carry them to the surface? It is only to surfaces that are hydrophobic and therefore poorly wetted by water that the gas has a chance of attaching itself. Typically, however, mineral grains in water are well wetted. To ensure that, in the end, the good ones end up in the pot – or, in this case, the froth – the valuable substances' wettability is chemically modified. "Reagents, so-called collectors, that are tailored to the respective valuable material make their surface hydrophobic while the other components remain hydrophilic," Martin Rudolph explains. "This means froth flotation can be customized to separate a wide range of minerals."

In addition to collectors, other activators like so-called depressants are used which improve the wettability of the unwanted grains, causing them to remain in the flotation cell. Chemicals called frothers help to stabilize the froth with the valuable particles so that the grains do not sink down into the fluid again. In order to float well, the grains need to be between 20 and 250 micrometers in size. The ore is ground as finely as necessary and selectively hydrophobized with collectors. It then enters the flotation cell as a watery slurry where a mixer generates and finely disperses air. The objective is to achieve as high an extraction rate as possible and this depends on various factors: the density of the slurry, the amount of gas added, the size of the particles and bubbles, the reagents used, and fluid dynamics – all of these need optimizing.

What happens at the surface?

“We can only make improvements when we know what exactly occurs during flotation, especially on the molecular level,” Rudolph believes. “When particles dispersed in water attach themselves to gas bubbles, three phases come together at once: solid, liquid and gas. We are interested in the interactions at the interfaces where the different materials make contact with one another.” The scientists focus on the particle surfaces where the collector and depressant reagents are applied as well as the hydrodynamic processes.

It is not only the surface properties of the minerals that interest the researchers but also how different reagents change the interaction forces in the flotation cell – the tank in which the processes take place. Given the increasing complexity of the ores with the most finely dispersed elements, this is a challenge. By using atomic force microscopy (AFM), the Freiberg group is able to investigate such complex mineral phases and characterize their wetting properties. AFM is an imaging method which makes it possible to visualize very small-scale topographies down to molecules. The scientists use it to measure the tiniest forces and thus to track down the interactions. This allows them to map the forces on the surface of fused raw materials and calculate the impact of reagents.

“With the measuring tool we have developed on the basis of atomic force microscopy we can quickly define the right chemical cocktail for floating a new raw material,” says Rudolph. “As this used to be a costly process in terms of both time and money, industry is very interested.” In the next five years, he and his team want to develop a prototype apparatus for screening flotation chemicals.

Flotation cell dynamics

The reagents are not the only things that influence the results of flotation, but also hydrodynamic processes. The flow conditions determine how often a particle collides with a bubble and whether the particle attaches itself to it. In investigating the complex hydrodynamics in the flotation cell, the HIF scientists work together closely with HZDR’s Institute of Fluid Dynamics and especially the Department of Transport Processes at Interfaces. The head, Kerstin Eckert, is a specialist in this field. “We look at the microprocesses and the inner dynamics of flotation through a very fine lens,” the physicist explains.

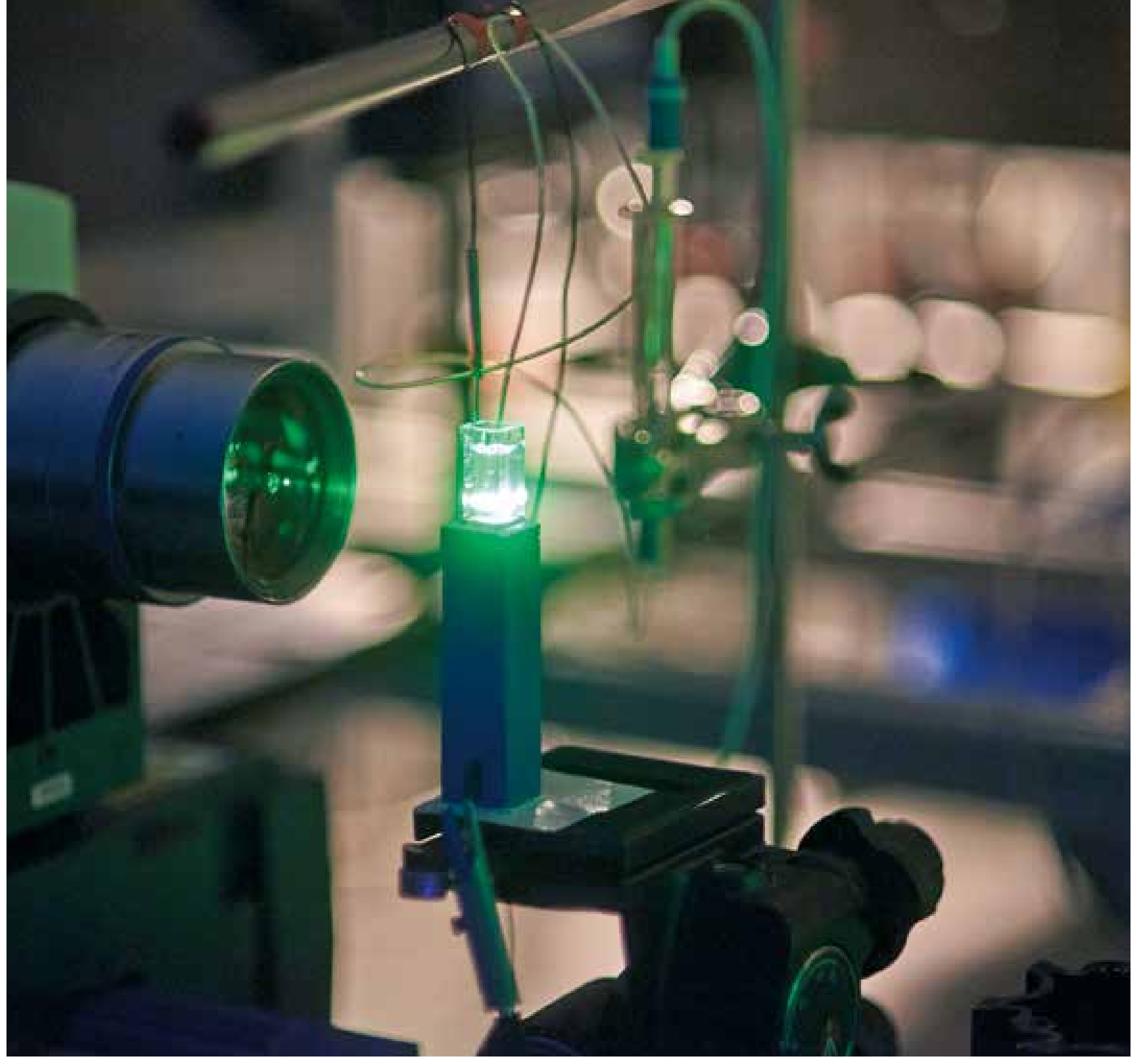
This research group focuses, above all, on fine grains of under 20 micrometers and particles that are too large to upwell in the froth. When it comes to ultra-fine particles, conventional froth flotation reaches its limits, which means that many valuable materials have been lost. The subject is also relevant for resource recovery from old waste dumps and recycling. Flotation could be a method for recovering and reusing the fine graphite and lithium containing particles in old batteries. Being able to float larger particles is worthwhile because coarser grains save energy on grinding.

The five-strong research group set up by Kerstin Eckert a year ago investigates the different effects at the interfaces in the slurry and froth phase. “This includes the electrical charges on bubbles and particles and the forces like surface tension and capillary actions,” the physicist explains. “We want to know how the dividing water film is broken when attachment takes place. This has to happen very quickly while the particle and the bubble are still close enough together.” To increase the chances of collision and attachment, the researchers are also studying measures to intensify the process, such as the application of ultrasound.

From an experimental point of view, the processes are difficult to follow because flotation literally takes place in the dark. All you can see is the input material and the final products. In order to understand what happens inside the black box, Eckert’s department conducts model experiments on sub-processes using new measuring methods. Neutrons, for example, are very good at shining “light” on the opaque frothing phase and the particle movements that take place in it. Just as important is the development of computer models. >

With a device known as an inverse gas chromatograph, Martin Rudolph can determine the surface properties of solids. Source: D. Müller

Flotation processes literally take place in murky waters. Source: D. Müller



That is why engineers and physicists at HZDR turn to lasers – in addition to atomic force microscopy – to shine some light into the darkness. Source: S. Floss

The mission of the researchers working with Martin Rudolph and Kerstin Eckert (pictured) is to better understand the underlying processes in order to optimize the method. Source: S. Floss

Simulation for greater accuracy

One approach is known as computational fluid dynamics. Team member Gregory Lecrivain is working on the development of a computer model to simulate particle attachment on gas bubble surfaces. Together with colleagues at Kyoto University in Japan he has already developed a three-phase model within the frame of the research project "CAPTURE". He has managed to simulate the attachment of hydrophobic particles to a rising gas bubble. "My aim is to continue developing the code so that we can recreate froth processing," the fluid mechanics specialist explains. "Due to the three phases and the high level of complexity it is very difficult, especially as numerical modeling is still in its infancy."

Attachment can only occur when air bubbles and hydrophobic mineral grains make contact. The bubbles often miss the very fine particles. Experiments in a bubble column are designed to elicit new insights into how collision frequency can be increased. By equipping model particles with fluorescent labels and using several high-speed cameras, the researchers can reconstruct particle positions and paths and measure collision and attachment with optical methods.

The results they achieve on microprocesses are entered into complex process models which simulate various parameters and should facilitate better predictions. In the future, they could replace the much more expensive pilot plants. "Unfortunately, you can't describe flotation in a single formula," says Martin Rudolph. "And in many areas, there are still a lot of question marks." His department consequently works in other fields, as well. A new project titled "MultiDimFlot" aims to develop a technology for separating ultrafine particles based on a number of characteristics like size, shape, roughness and surface wettability.

In the meantime, Kerstin Eckert's research group is working on further froth flotation applications. She is examining whether the method is suitable for separating microplastics and textile particles. Because microplastic particles are usually coarse and have external air pockets, the question is how this will affect the flotation process.

In her role as coordinator for the NetFlot Network, Eckert also seeks to connect flotation expertise at European level and expand their international presence. Both project leaders agree: "So far, countries like Australia and Canada are heading the field in this area, but at conferences we have observed that much more attention is now being paid to our research."

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When the wind stops blowing

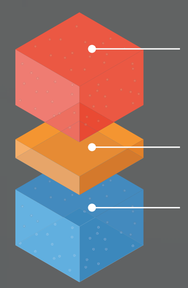
With the closing down of its nuclear power plants by 2022 and the planned decommissioning of its fossil fuel power stations, Germany is transitioning to an energy supply based mainly on intermittent renewable electricity sources.

_Text . Simon Schmitt _Illustration . Ressourcenmangel

NEW STORAGE OPTIONS FOR FLUCTUATING CURRENT FLOW

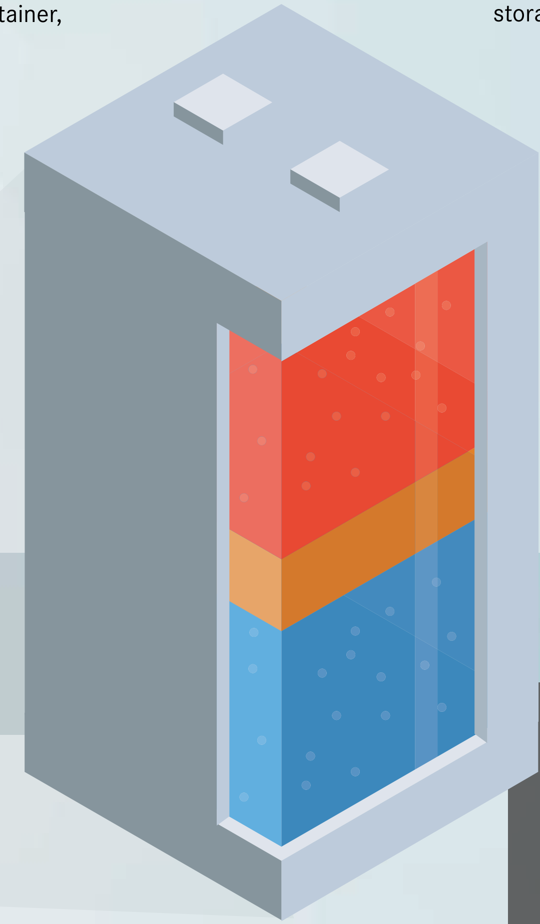
By expanding the electricity grids and by deploying power plants generating energy from renewables like wind and solar, many experts believe that this transformation is comparatively easy to achieve. By far the greater challenge will be to compensate for the concomitant fluctuations and to secure a reliable power supply always matching the demand. For this purpose, efficient methods are required, especially for long-term storage. Engineers at HZDR are working on a solution that could potentially store vast quantities of electricity very cheaply: a liquid metal battery. But, at present, scalability is still giving researchers a headache.

EXAMPLE



A LAYERED BATTERY

In effect, the basic principle of a liquid metal battery is relatively simple – it rests on two physical facts: On the one hand, immiscible liquids of differing densities form layers; on the other, liquid metals conduct electricity, so they can act directly as anodes and cathodes. If you pour two appropriate metals such as sodium and bismuth into a container, the heavier material will automatically sink to the bottom. By separating the metals with a layer of molten salt, a galvanic cell is created. Because the metals want to form an alloy, their atoms first have to release electrons in order to be able to pass through the fused salt as ions. On the other side, they alloy with the metal by gaining electrons. When charging, this process is reversed – the alloy once more separates into its constituent parts. “This means the battery can be charged and discharged as often as you like,” explains Tom Weier who is developing the novel storage device together with his team. “That’s what makes it economically viable. Moreover, the system is able to respond over a very short time span and can flexibly react to changes in supply or demand.” The HZDR researcher believes single cells with an area of several square meters are conceivable.



TURBULENCE IN THE SYSTEM

Increasing cell size, however, which would be necessary for large scale deployment, poses a problem. As the currents that flow through the liquid metals are extremely strong, electromagnetic instabilities can occur, causing violent motion. In the worst case, this could deform the separation layer so that the two metals make direct contact which would result in a short circuit and the loss of the stored electricity. In order to tame the flow, the Dresden scientists have developed and patented various solutions which guarantee the integrity of the salt layer. At present, the lab-scale cells deliver two amperes of electricity per square centimeter electrode area at an operating temperature of 400 degrees Celsius.

»

> “Storing electricity in periods of over-supply, the liquid metal batteries could always release power when the sun stops shining or the wind turbines grind to a halt.”

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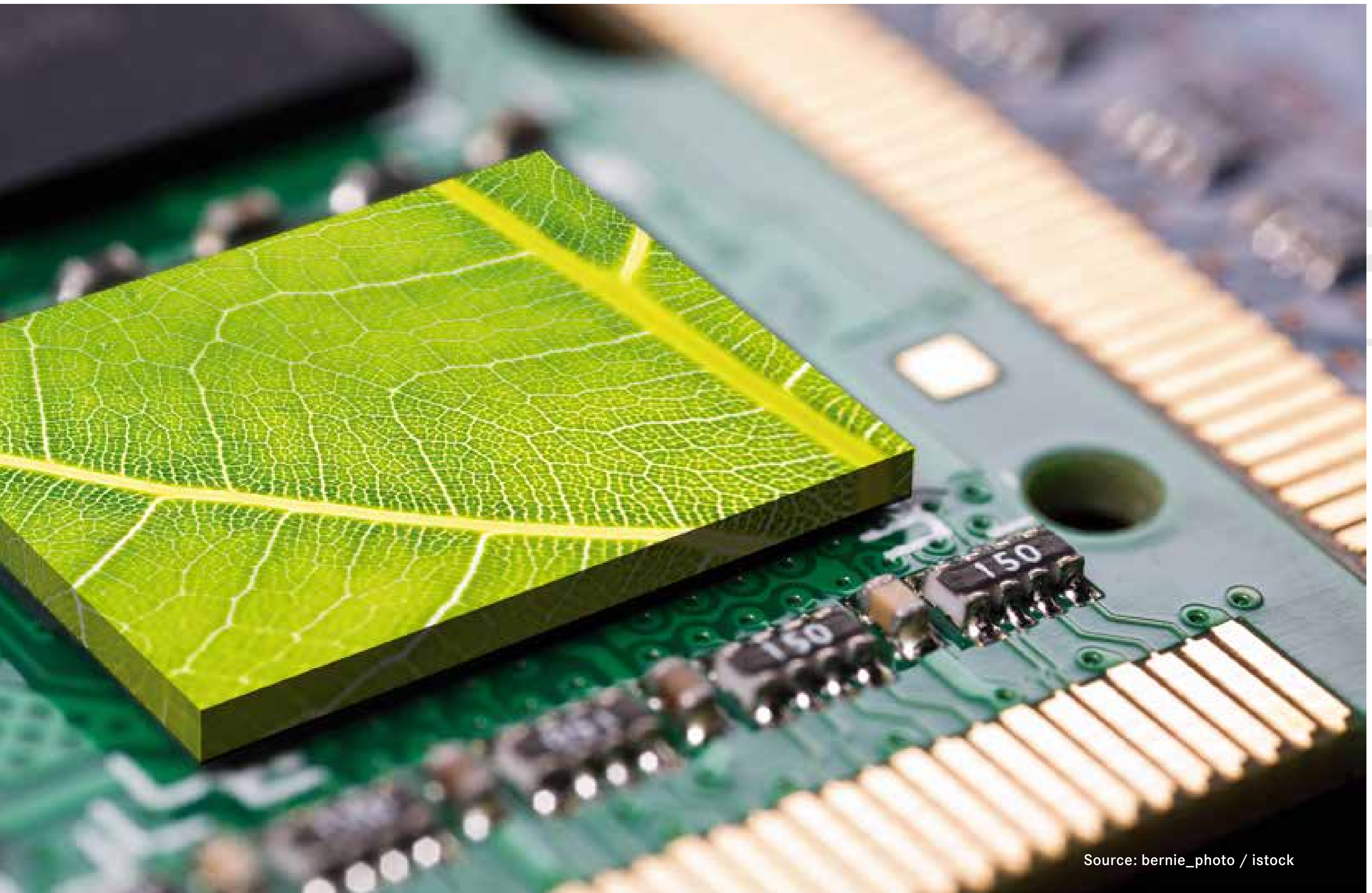
Energy diet for microchips

Electronic devices' thirst for energy is constantly increasing – there are simply ever more of them. HZDR researchers are developing strategies to ensure that future computers and data storage can thrive on far less.

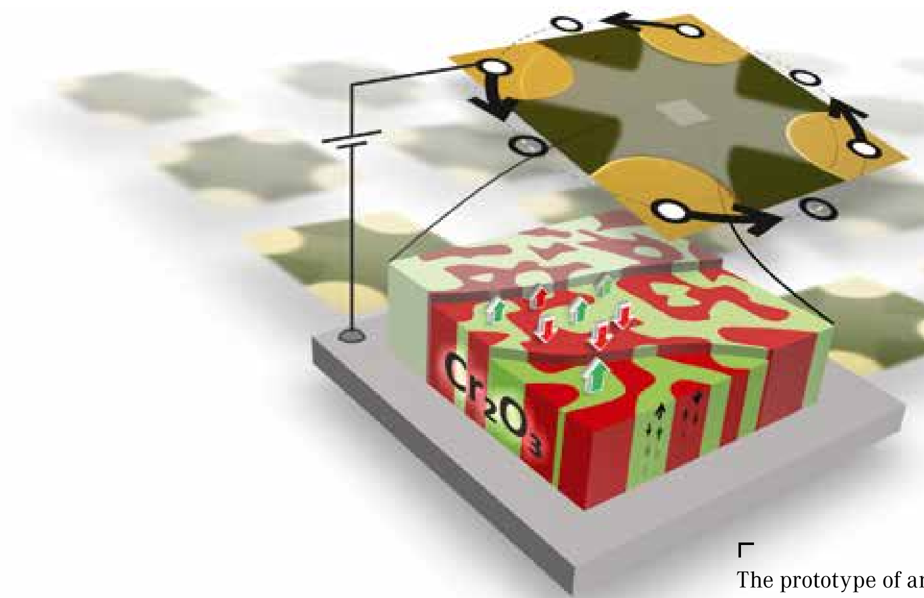
_ Text . Frank Grotelüschen

Internet searches, database queries, video conferences – the office computer runs at full speed all day. Taking a lunchtime peek at your smartphone, checking your email and your social networks. And then in the evening, sitting comfortably on the sofa watching a stream of the latest episode of your favorite series. This is roughly the shape of many people's daily lives – totally connected, including gigabyte flat rates and digital subscriptions. But such intensive use of the internet comes at a price: computer farms, data centers and terminals use ever more power, energy costs and greenhouse gas emissions grow. It has been estimated that, even today, 25 large power stations are needed to produce electricity for the worldwide internet – and the trend is upward.

This is why researchers in Dresden are working on strategies to quench electronic components' thirst for energy. In order to develop such energy-efficient electronics, the experts are investigating different forms of leverage: some are working on extremely energy efficient storage chips, others are drawing up strategies to exploit the waste heat from circuits as an energy source.



Source: bernie_photo / istock



The prototype of an antiferromagnetic magnetoelectric storage chip comprises a thin layer of chromium oxide for storage. Superimposed on this is an ultrathin layer of platinum that is used for readout. Source: T. Kosub

Magnetic random access memories are among the most promising technologies towards reliable, fast and energy efficient memory chips. So far, electric currents have been used in the switching process for writing and reading data on storage chips – with considerable loss in the process. "Only about five percent of the energy used actually goes into the storage process, the rest is wasted," explains Denys Makarov, group leader at HZDR's Institute of Ion Beam Physics and Materials Research. "That's about as efficient as a light bulb."

This state of affairs almost forces today's internet companies and cloud providers to build their water-cooled computer farms in northern latitudes. Only in a cold climate can the facilities be cooled efficiently. Given that the demand for storage capacity will continue to rise in the future, the situation is bound to get even more difficult. "In my opinion, power consumption is the biggest problem we'll face in data storage," says Makarov.

Voltage instead of current

Therefore, his team together with colleagues from the University of Basel and the Leibniz Institute for Solid State and Materials Research Dresden is attempting a veritable paradigm shift: instead of current, electric voltage stores and reads the data. This approach should bring enormous savings. "Basically, the energy consumed by a storage cell could be reduced to a hundredth," Makarov's colleague Tobias Kosub explains. In 2016, the physicists produced a prototype to demonstrate the idea at a proof-of-concept level, managing to solve a major scientific and technological problem.

The core of the new storage element is a thin layer of chromium oxide – a so-called antiferromagnetic magneto-electric insulator. Put simply, this has an inner magnetic orientation that can only point in two directions. One is equivalent to a digital "1", the other to a digital "0". But for many years, experts did not know how such a storage element could be efficiently read. Up to now, a further ferromagnetic component was required which largely compromised the advantages of the concept. Last year, the researchers managed to solve the problem. With the help of a physical phenomenon, the anomalous Hall effect, they were able to directly access the bit they had previously stored in the antiferromagnet. "In this way, the signal can be read very reliably," says Kosub.

While the scientists fabricated a single bit in their prototype at the beginning, they now work on further prototypes, which can store several bits. For applications, of course, the number would have to be increased significantly, as Denys Makarov is only too aware: "But this technology development can't be done in a research lab. This is where industry would have to step in."

Instead, the HZDR researchers are now busy refining their method and making it more sensitive. "Apart from this, the components need to be miniaturized," Makarov explains. "Only then will industry show an interest in the idea." The current prototypes are in the micrometer range, but what is needed are dimensions of a few dozen nanometers. This is, however, difficult with chromium oxide as the active material. The experts are consequently testing other antiferromagnetic materials.

Cloud economy drive

"Our group is particularly good at measuring new prototypes," says Makarov. "In our lab we examine samples from research teams all over the world." For this purpose, the Dresden scientists have constructed electronic measuring equipment that can measure electrical quantities, such as resistance values, with the utmost level of precision. As part of a spin-off, a team working with Tobias Kosub is currently developing the patent into a product – a tool that could be of interest not only for research labs but also for industry. >

Source: Shai_Halud / Shutterstock

Tobias Kosub (right) works on novel storage chips which could significantly reduce power consumption. Source: S. Floss

If the “energy-diet storage chip” reaches the commercial stage one day, the first products will probably be found, above all, in niche markets. On satellites, for example, power is often at a premium – power-saving storage chips would be extremely useful. They could, moreover, be more reliable than conventional components and less sensitive to electromagnetic interference. The new method also holds promise for applications in the automotive industry – it could work more reliably and be less susceptible to interference than the components currently in use.

For it to be utilized in cloud data centers, however, major obstacles would have to be overcome. At present, hard disks are the storage norm – and they are serious energy guzzlers. “Our technique could save a lot of energy,” Makarov emphasizes, “but it could prove hard to compete economically – hard disks are dirt cheap.” But in the long-distant future, the new method could score with another advantage: It facilitates faster writing and reading speeds than a hard disk and that could become particularly relevant if future internet lines enable data to be transferred more quickly. Storage chips based on antiferromagnets might also be relevant for portable terminals. And they would then be well equipped for the ultrafast network of tomorrow.

Power source: waste heat

An alternative approach is being investigated by another HZDR team in the same institute. “Everyone who handles a smartphone notices that it’s warm because the chips heat up during use,” says head of division Jürgen Lindner. “We’ve come up with an idea for recovering some of this waste heat.” It works on the principle of attaching a very thin layer composed of a special, heat-insulating permanent magnet underneath a conducting path, which is automatically heated up by the electric current. The magnet offers the exciting possibility of directly transforming part of the waste heat into a high-frequency signal. This in turn could then power other components directly, such as the transmitting chip in a cell phone or the clock generator in a processor.

A clever way of recovering energy based on the following mechanism: Although the thin magnetic layer is heated up by the conducting path immediately above it, it is not a good heat conductor and the heating is extremely uneven: directly at the interface, the magnetic layer assumes the same temperature as the conducting path, but below, it is significantly cooler. At first sight the difference of approximately six degrees does not sound like much. But if you consider that the layer only measures a mere 20 nanometers, that is an extreme drop in temperature – as though the head side of a coin were half a million degrees warmer than the tail side.

Recovery in microcosm

The drop in temperature has a strange effect on the electrons in the two materials, the conducting path and the magnetic layer: It acts as a driving force for so-called spin current, a kind of “magnetic migration” which causes magnetic oscillation to develop in the extremely thin magnetic layer; like a bicycle dynamo, it can be transformed into an alternating electric field and thus rendered utilizable.

In order to check whether the idea could be put into practice, Lindner and his colleagues built a prototype: a magnetic nano-oscillator through which the magnetism generated by the spin current oscillates. The component consists of a platinum strip a few micrometers long and 300 nanometers wide. Underneath this strip a thin layer of yttrium iron garnet, YIG, is adhered which conducts neither electricity nor heat. “Together with physicists in California we demonstrated that you really can produce a high-frequency signal using temperature difference,” says Lindner. “And so, we proved that the idea works.”

But before there can be any thought of technical applications the physicists still have fundamental questions to answer. “There’s a second phenomenon that produces high frequency in the YIG layer,” Lindner explains, “because the direct current that flows through the platinum not only heats the metal but automatically induces a kind of magnetic gyroscopic effect, as well.” While measurements suggest that the impact of this effect is less than that of the high-frequency produced by the drop in temperature, the researchers will only know for sure once they have conducted further tests: Instead of employing electrical current through the platinum to heat the YIG strip they plan to use a laser. This would switch off the “direct-current effect” so that they could directly control the impact of the drop in temperature.

So, how efficient is the process, how much waste heat can be turned into utilizable high frequency? “We haven’t been able to measure that yet,” says Jürgen Lindner, alluding to future experiments. But one thing seems to be sure: The YIG in its present form is not suitable for commercial exploitation – it is simply too expensive. This is why the material researchers are already searching for cheaper, more effective alternatives. “With the right materials and an optimized method of decoupling the high-frequency signal, in principle, I think, it might be possible to achieve a conversion rate of several ten percent,” says Lindner. This would mean that more than half of the waste heat could be transformed into utilizable high frequency. The first field of application might be in space: power is precious on space probes, recovering waste heat could prove more than worthwhile.

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Back to the factory instead of in the garbage

Developments in waste management are supposed to be heading towards a circular economy: in accordance with this ideal, all the material used in manufacturing a product should be recyclable at the end of its lifespan. But a lot still has to happen before we get that far. As studies have shown, when it comes to electronic waste, modular construction and smart sorting would help to recycle valuable metals.

— Text . Sven Titz

Today, nearly everyone has a smartphone. Many people buy a new one every two or three years and the old one then often lies around in a drawer for even longer. But what to do with it? Although the devices contain valuable materials, especially rare metals, not enough smartphones are appropriately recycled. Some even end up – quite illegally – in household waste. In Germany, the aim, in theory, is to establish a circular economy. But in 2014, the recycling share of total materials used was only 17 percent. The figures were much the same for electronic waste, which includes tablets, laptops, PCs and numerous other everyday devices: we are still falling considerably short of this ideal.

A research project on smartphones illustrates the potential of a circular economy for electronic devices, but also its limits. The project was headed by Markus Reuter, Director at the Helmholtz Institute Freiberg for Resource Technology. Together with his colleague Antoinette van Schaik from the Dutch company MARAS B.V., he tested the recycling capability of "Fairphone-2". This model, produced by the firm Fairphone, is specifically built with transparent production and reusability in mind. For this purpose, the developers constructed it using seven modules.

In 2016, the firm approached Schaik and Reuter because they were interested in their software which can simulate entire raw material paths – including the recycling process. The software can reveal how much of a substance can be recovered through various recycling methods.

Modular construction ideal for recycling

In the study, the researchers tested three recycling routes: the first involved melting down the Fairphone-2, the second, disassembling the modules, and the third, shredding. "If, all in all, you want to minimize the damage, the module method of recycling scores best," says Markus Reuter, summarizing the results. "Using this technique, substances like gold, copper, silver, cobalt, nickel, palladium, platinum, gallium, indium and zinc can largely be recycled. But even with the disassembly option you can only recover a limited amount of many substances – for example, the metals tantalum and tungsten." The crux in electronic devices like smartphones is the incredibly close chemical and physical connection of the raw materials. "Many parts are stuck together, some substances coated, others attached by electrolysis, yet others are alloys," explains Reuter. This makes recycling much more difficult. And even what is technically possible is not always sensible. In some metals the concentration is simply too low to warrant recycling.

In the same study, the environmental impact of the methods for recycling the Fairphone-2 was tested. In addition to material wastage, energy requirements, climate impact and the handling of recyclable or combustible plastic were evaluated. The modular method came out on top in this test, too, and is consequently the clear recommendation of the study.

The story of the Fairphone-2 was a "great thing", according to Christiane Schnepel, head of Product Stewardship and Waste Management at the German Environment Agency. It considered the entire supplier chain from the point of view of sustainability, says the engineer, full of praise. But Schnepel points out that in addition to smartphones, one should not forget all the other electronic equipment which contains similar precious and special metals.

The pitfalls of sorting waste

When electronic devices have to be scrapped, the question has to be asked as to how scrap of this kind should be disposed of. In Germany, this is regulated by the Electrical and Electronic Equipment Act, known as "ElektroG", which seeks to protect the environment from the harmful substances in the devices. The law is, moreover, supposed to ensure that as many resources are recovered as possible. ElektroG stipulates, for example, that traders of a certain size upwards are obliged to take back old devices in order to channel them into recycling.

To ensure that the disposal companies concerned deal with the old electrical equipment wisely, new handling regulations are on the drawing board. For this purpose, the UBA – together with 200 representatives of industry, institutes, environmental associations and authorities – drew up a list of recommendations in an open process launched in November 2015, Schnepel reports. It has identified several typical concerns, such as the meaningful sorting and disposal of harmful substances in scrap. >

Source: Lya_Cattel / istock

Take the recommendation on photovoltaic modules: they are supposed to be separated from demolition waste and then break-proofed for the transfer to final disposal. Some photovoltaic panels are coated with toxic cadmium telluride, which makes special demands on the disposal process.

Another recommendation deals with the circuit boards in electronic equipment. Concentrations of a relatively large number of precious and special metals are to be found on circuit boards in hard disks, routers, cell phones and computers. The best way of recovering them is by removing the circuit boards before the devices are shredded. Then this separated "fraction" of circuit boards can be prepared for recovery using specific metallurgical processes which release the valuable metals. If, on the other hand, the devices are completely shredded, the metals end up with the plastics and are no longer recoverable.

Rare metals in electronic waste

Environmental protection is not the only reason why the circular economy is an objective. The efficient handling of resources is another motivation. In the long term, economic growth should be decoupled from the use of resources. Consequently, last year, the government updated the "German Resource Efficiency Programme" to 2020. At EU level, as well, efforts are being made to reduce dependency on the import of critical metals.

The idea that you can only extract metals from ores became obsolete years ago. Two comparisons demonstrate just how big the recycling potential really is: Germany's total annual waste production contains more copper than is extracted in the world's largest copper mine. And a ton of cell phones boasts roughly 50 times as much gold as a ton of auriferous ore.

For years, substances like cobalt, lithium, indium, gallium and Rare-Earth metals such as neodymium have been a particular focus in planning for the circular economy. Not least as a result of the *Energiewende*, which means that many renewable energy generation plants have to be built, they are in ever greater demand. In many cases, however, there are no, or no viable, methods of recovering the relevant substances from the scrap.

Lithium, for example, can be found in batteries in many devices, and electromobility is likely to increase the demand for lithium yet more. Chile and Bolivia are home to two-thirds of the resources of this metal and they could be exhausted in the foreseeable future. It would, therefore, be helpful if the lithium in batteries could be recycled. So far, this has been complicated and expensive. Recently, however, researchers at Technical University Bergakademie Freiberg seem to have found a way of applying a new method that could make it possible to recover lithium from batteries at an acceptable cost.

Significantly more critical would seem to be the supply of cobalt, which is often used for battery cathodes. That was the conclusion drawn from an analysis of lithium-ion battery supply chains conducted by researchers at Massachusetts Institute of Technology in Cambridge. Currently, cobalt is largely mined in the Republic of Congo. At least for this metal, however, there are already commercially worthwhile recycling processes.

Just these few examples clearly illustrate how big and complex the challenge of changing to a circular economy really is – particularly in the case of electronic scrap. This is why Markus Reuter wants to see a more realistic assessment of the potential of the circular economy. He likes to compare a smartphone with a cup of sweetened latte: "There is no economic way of retransforming it into coffee grounds, water, milk and sugar. It will never be possible to recycle a hundred percent of the material in complex devices. But we can do a lot better than we are at the moment."

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Elizabeth Green scrutinizing samples in the High Magnetic Field Lab. Source: S. Floss

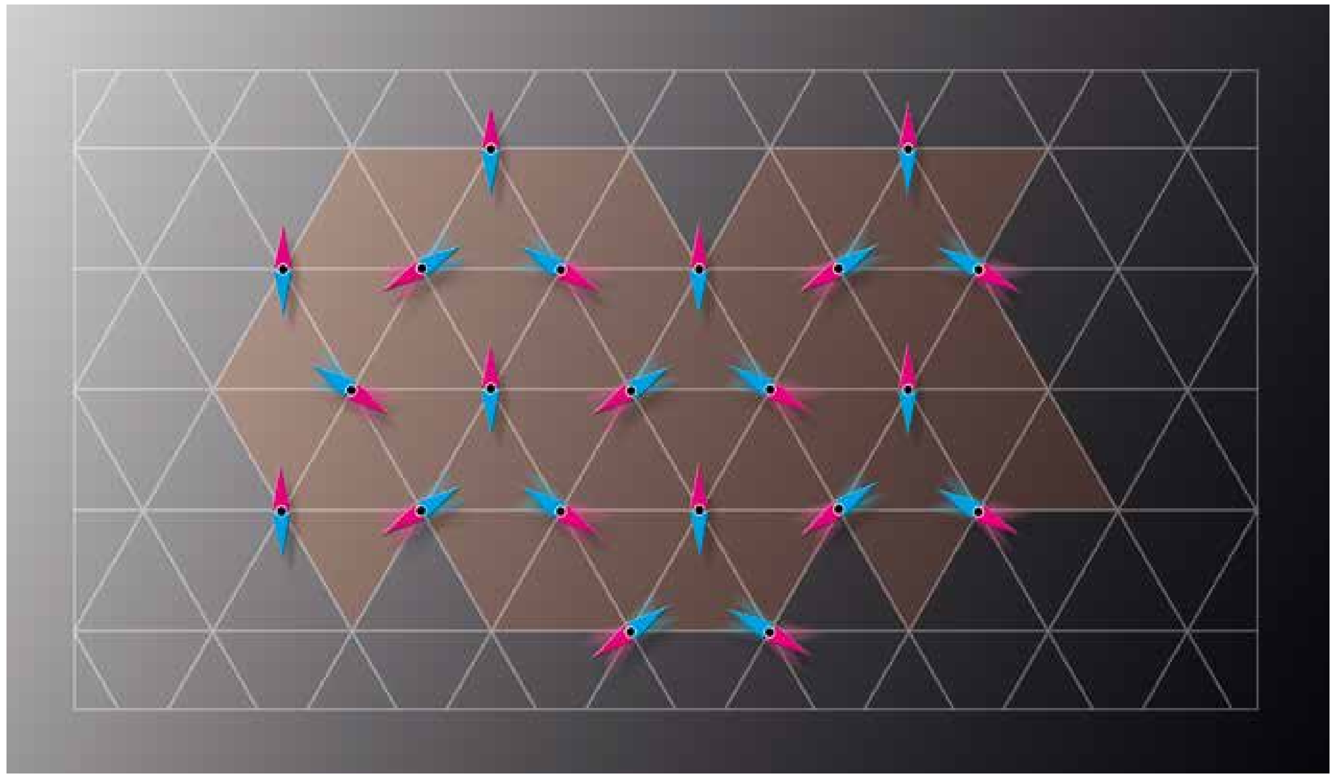
When magnets become frustrated

The Dresden High Magnetic Field Laboratory generates extremely powerful magnetic fields, allowing scientists to explore novel states in an unusual class of materials – frustrated magnets. The result is new fundamental knowledge about the behavior of state systems.

_ **Text** . Frank Grotelüschen

A metal cylinder is on display in the hallway of the Dresden High Magnetic Field Laboratory (HLD). It is about the size of a washing machine drum in diameter, its bottom and lid are secured with massive bolts. "This is a decommissioned magnetic coil," explains Sergei Zherlitsyn, physicist at the Helmholtz-Zentrum Dresden-Rossendorf. "These are the coils we use to generate some of the strongest magnetic fields on the planet." When researchers expose certain materials to these fields, they get clues about new, exotic states of matter – phases whose inner order is similar to a liquid crystal, or indications of a unique quantum state: supersolidity.

Specifically, the HZDR experts are studying the material class of frustrated magnets. Visualize a normal magnet as a place packed with compass needles that often mutually align and thus assume a rather strict order: In regular magnets, these compass needles, or "spins", either point in the same or in the opposite direction.



Electron spins – represented here by compass needles – often try to point in the opposite direction from their neighbors. With certain spin alignments this is not always possible, which leads to frustrated states. Source: M. Voigt

A frustrated magnet is different: "In certain crystal lattices, there are three spins that react to each other," physicist Elizabeth Green explains. "Two of them can mutually align and point in opposite directions. The third one, however, doesn't really know what to do and where to point – it is frustrated." Metaphorically speaking, imagine three people. Two know exactly where to go – and the third one doesn't know which of the two others he's supposed to follow. The third person is consequently disoriented and therefore frustrated.

Sergei Zherlitsyn explains what is special about this class of substances: "Frustrated magnets can give rise to new, unique states of matter. However, these states often only occur when you subject the sample to extreme conditions, such as strong magnetic fields, low temperatures, or high pressure." Conditions like this can be created at the HLD. It can generate magnetic field pulses of more than 95 tesla, two million times stronger than our Earth's magnetic field.

Super coils in a corset

The coils had to be custom-built: The experiment is set up inside a rod wrapped in several layers of metal wire. Electric currents of up to 60,000 ampere flow through these wires, creating extremely strong magnetic fields. And because this level of energy threatens to burst the wire coil, it is stabilized by a corset-like fiber fabric that can withstand pressures 40,000 times greater than our atmospheric pressure. However, this extreme state can only be maintained for a fraction of a second – the magnetic field does not last, it is pulsed. The short electric pulses that feed the coil emanate from a capacitor bank that is housed in a room the size of a gym. "We have two of these capacitor banks. They are the largest of their kind in the world," explains Sergei Zherlitsyn, pointing to metal frames packed with massive electronic equipment, a total of 500 single oil-filled capacitors.

It takes about a minute and a half to fully charge them. Then, they are remotely discharged from a control room in an instant, sending a powerful electric pulse to one of the ten experimental cells where the cylinder-shaped magnetic coil sits in a pit with thick concrete walls. A host of cables and tubes lead to the magnet, cooling it with nitrogen, supplying it with electricity, and connecting it with measuring sensors. While a pulse only lasts a fraction of a second, it takes hours to prepare it. After the pulse, the researchers can instantly verify on their monitors whether the measurements worked according to plan.

"No one is allowed in the experimental cell during the experiment," says Zherlitsyn, "because we push our magnets to the very limits of their strength – and sometimes beyond."

As proof, fragments of a burst magnet are displayed in the small exhibition area at the High Magnetic Field Lab. "Sometimes the magnets fail and burst during the experiment," says the physicist. "They experience a lot of stress during the experiment, which is why they have a limited lifetime – we keep building new ones in our workshop."

Some time ago, these kinds of experiments led Zherlitsyn and researchers from Augsburg and from Chişinău (Moldova) to a remarkable discovery about the strange quantum phenomenon called supersolidity. In this state, a material shows both solid and superfluid properties. In a superfluid state, liquids can creep up the walls of a container without any resistance – provided that they are ultracold.

It is assumed that supersolidity exists in solid helium at extremely low temperatures. Empty spots in the crystal lattice, normally populated by helium atoms, are thought to be able to move through the crystal without any resistance – as though the substance were solid and liquid at the same time. A number of experiments point to the existence of this paradoxical effect. This year, two research groups were able to observe strong indications of supersolidity in an extremely cold atom cloud called a Bose-Einstein condensate.

Solid and liquid at the same time

Thanks to their experiments with frustrated magnets, Sergei Zherlitsyn's team has now provided another indicator. "We observed properties similar to supersolidity in a compound of manganese, chrome and sulfur," the physicist explains. "But in our case, it isn't particles that are moving around, but electron spins." Formally, the same theory describes both phenomena. The spins' supersolid behavior supports the assumption that this strange quantum phenomenon really exists.

Similarly baffling are the findings of Elizabeth Green's research collaboration, which includes experts from Dresden as well as from Stuttgart, Grenoble, and Toulouse. "A compound of lithium, copper, vanadium, and oxygen indicated that in high magnetic fields, the spins assume an order similar to the structure of liquid crystals," Green describes. What is fascinating about this is that, unlike conventional magnets, these materials only possess a magnetic order in one spatial direction and not in others. While the experiments delivered promising indications of the existence of such a "nematic phase", further experiments are needed to acquire definitive proof.

So, what is the practical use of these experiments? "So far, this is pure fundamental research," Green responds. "We don't know yet whether it will lead to concrete applications one day." Nonetheless, some experts are already speculating that frustrated magnets with their exotic states could serve as the basis for a revolutionary kind of computer – the quantum computer, which in many ways would outperform even the best supercomputers.

Publications:

V. Tsurkan, S. Zherlitsyn, L. Prodan, V. Felea, P.T. Cong, Y. Skourski, Z. Wang, J. Deisenhofer, H.-A. Krug von Nidda, J. Wosnitza, A. Loidl: Ultra-robust high-field magnetization plateau and supersolidity in bond-frustrated MnCr2S4, Science Advances, 2017 (DOI: 10.1126/sciadv.1601982)

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Sergei Zherlitsyn (right) was one of the developers of HZDR's record coil. With the help of a special machine, the physicist and his co-worker Oliver Kersten (left) can wind the coils. Source: J. Jeibmann

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Color lies in the beholder's ... gender

Color perception is a wonderful topic to argue over. Researchers from Nigeria and Leipzig (Germany) have discovered that male and female mice process the color blue on different sides of their brains – and exactly the opposite way that humans do.

_Text . Roland Knauer

Source: Deagreez / istock

At first, brain researcher and neurosurgeon Philip Njemanze from the Chidicon Medical Center in the Nigerian metropolis of Owerri could hardly believe what he had discovered. In special ultrasound studies conducted in his home country, he had observed that men perceive blue light on the right side of their brains, while women use the left side. In order to take a closer look at this astounding finding, the African researcher discussed it with HZDR experts Peter Brust and Mathias Kranz from the Institute of Radiopharmaceutical Cancer Research, because their methods at the Leipzig research site allow investigating the differences in far greater detail. Use of a comparable protocol for color perception in mice brought the next surprise: While the rodents also process blue light in different cerebral hemispheres, the sides seemed to be reversed compared to humans.

What had happened? At first, Philip Njemanze believed there might have been a mistake. "He asked me if I might have gotten something mixed up when I analyzed my data," recalls Mathias Kranz, who had performed the experiment. This sort of question is daily routine for a natural scientist, so the medical physicist started looking for answers. He found no error. There was no mix-up, everything had been analyzed correctly. That could only mean one thing: Apparently, mice process the color blue on a different side of the brain than we humans do. So, in addition to gender-based differences in color perception, there are also species-based differences.

New methods to decode color perception

Sensory physiologists all over the world are still trying to figure out how such differences emerge and what their implications are. While human color perception is pretty well documented, there's still a lot we don't know about how animals see color. Sensory perception involves two major steps: There's the reception of the signal itself, and then there is how we process these stimuli in our brains, which can only be studied in living organisms.

For instance, the human eye has tiny structures called rods that give us black-and-white vision including the grayscale. In addition, our eyes feature three different types of cones. One of them is particularly sensitive to visible short-wave blue light, another one responds best to green light of medium wavelengths, while the third one is in charge of long-wave red light. Many animals have these cones, as well. Many mammals, however, only have two different types of cones, while many birds and reptiles even have four.

All these receptors merely deliver signals. In a second step, the brain then processes them into color vision. Observing these processes in the cells of a living human or animal requires sophisticated techniques, many of which have only been developed in recent decades.

The cells' treacherous energy consumption

One of them is the Doppler ultrasound method, which Philip Njemanze used to analyze his students' color perception in Nigeria. The researcher measured how fast blood circulates in certain areas of the brain. Since it is the blood that delivers energy to the tissue, more blood circulating in a certain area of the brain strongly indicates elevated energy use in these cells. Male students showed particularly intense activity on the right side of the brain when they saw blue light, while their female counterparts apparently processed blue on the left side.

However, a better way of measuring blood flow than with a Doppler ultrasound would be to measure energy metabolism in the cells directly. And that is exactly what HZDR researchers Peter Brust and Mathias Kranz did. They replaced a small part of the sugar glucose – which is the major energy provider in the blood – with a similar compound named [^{18}F]fluorodeoxyglucose (FDG), which contains a radioactive fluorine-18 atom. The organism confuses this FDG with glucose and tries to use it the same way. A part of the substance remains inside the cell, along with its fluorine-18 atoms.

Half of these radioactive atoms decay within 109 minutes, radiating positrons, which quickly collide with electrons in the environment. Both particles convert into gamma radiation, which researchers can detect using measuring devices. The more gamma radiation emanates from one region of the brain, the more fluorine-18 must have been trapped there, so more energy is apparently being used there. This positron emission tomography (PET) is often used in medicine, for example, to detect brain diseases or tumors.

Source: Deagreez / istock

Mice see it differently

The researchers in Leipzig used this diagnostic method on mice, as well. In experiments on male mice, the radioactive sugar accumulated to a much higher degree in the left cerebral hemisphere, that is the opposite side from the Nigerian male students. Female mice used a lot more energy on the right side of their brains.

"It was a huge surprise to find that perception of the color blue has evolved differently in mice than in humans," Mathias Kranz marvels. When we asked him why that is, he responded with a shrug: "No one knows so far. But our colleagues in Nigeria are going to pursue this question further."

Publication:
P.C. Njemanze, M. Kranz, M. Amend, J. Hauser, H. Wehrl, P. Brust: Gender differences in cerebral metabolism for color processing in mice: A PET/MRI study, PLOS ONE, 2017 (DOI: 10.1371/journal.pone.0179919)

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At the very bottom of the periodic table

Each spring, numerous young scientists eagerly await a letter from the European Research Council (ERC): They want to know if they have been chosen for one of the coveted "Starting Grants" for talented scientists, endowed with up to 1.5 million euros each. Kristina Kvashnina was among the few chosen ones this year. At the Rossendorf Beamline ROBL, which HZDR operates at the European Synchrotron Radiation Facility in Grenoble, the physicist studies elements at the lower end of the periodic table. *discovered* talked to her about the project.

_Text . Simon Schmitt

Source: ESRF / Molyneux

ERC Starting Grants – funds for promising young researchers

The ERC awards its 'Starting Grants' to support excellent researchers as they embark on independent careers. Depending on the research field and career phase, the selection is based on criteria including the proposed project, publications, patents, lectures at international conferences, and science awards. The European Union provides the funds for ERC grants from its "Horizon 2020" Framework Program for Research and Innovation. This year, the ERC selected a total of 406 projects from 3,085 submissions, i.e. a success rate of 13 percent. Following in the footsteps of Markus Schubert and Denys Makarov, Kristina Kvashnina is the third HZDR scientist to secure an ERC Starting Grant.

discovered: Mrs. Kvashnina, your research is mainly focused on elements that belong to the lanthanide and actinide series. These include uranium and plutonium, but also some rare-earth elements. The last element of these two series was discovered as early as 1961. What is left to explore?

Kristina Kvashnina: Quite a lot, as a matter of fact. These elements have many fundamental properties that we don't fully understand yet, for example, how they form chemical compounds. That is a big issue, in particular for the safe long-term storage of radioactive waste. We don't have a precise enough understanding of how these radioactive elements behave in nuclear waste repositories. We will be able to make much better predictions once we learn about their fundamental structures.

Why is there so much we don't know yet?

Even though the topic is very important, the scientific community in this research niche is rather small. This is mainly because most institutes don't have the capabilities to conduct the necessary experiments. Not all labs are permitted to work with radioactive actinides. This is why we prepare our samples at HZDR, one of just a few facilities in Europe that is approved to handle higher concentrations of radionuclides. The experiments themselves can only be performed at ROBL. Our international cooperation puts us in a pretty unique position to conduct our experiments. That was also the reason why two years ago, I switched within ESRF from another beamline to ROBL.

What roles do the lanthanides play in all this?

The lanthanides are similar to the actinides, but unlike actinides, most lanthanides aren't radioactive. This makes them very suitable as comparative systems for simulations and theoretical models. Some elements in this series, such as praseodymium or europium, have luminescent properties that are of great interest for biomedical applications, which is why they are used in nanomaterials. The nano-level, however, is exactly where the physical and chemical properties of substances change. That is what we need to study very closely.

What happens in your experiments?

Imagine the entire set-up as a gigantic microscope. We expose the substances to high-brilliance X-rays from the synchrotron – similar to a hospital setting, but about 100 billion times stronger. And we're not looking inside the human body, but rather penetrating much deeper into the matter itself. We want information about the chemical structure of the substances and the behavior of their electrons. In order to obtain this, we joined forces with corporate partners to develop a novel X-ray spectrometer, the first one to combine high-energy resolution with the low detection limits that are necessary for actinides. We are currently installing the facility at ROBL. The project will be a great opportunity for our Ph.D. candidates, in particular, to learn how to apply various analytical methods.

What does the EU grant include?

The ERC grant will provide about 1.5 million euros for my research over the next five years. I will use these funds to build my own research group, which will probably include three post-docs and two Ph.D. candidates at ROBL.

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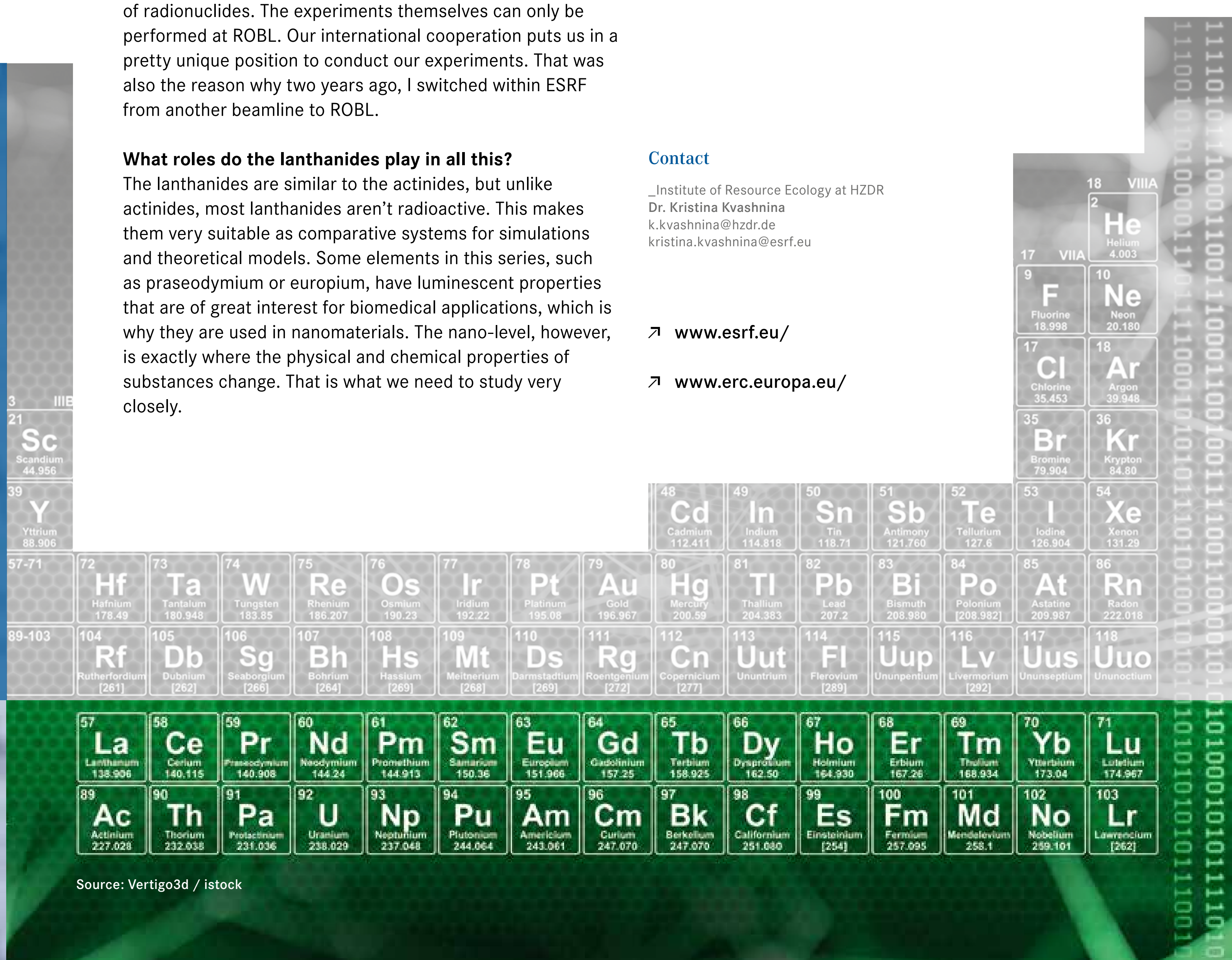

Source: Vertigo3d / istock

OFF THE GROUND

Smart young talent for smart sensors

On 1 September, the Helmholtz-Zentrum Dresden-Rossendorf joined forces with twelve research institutes and 15 corporations from nine countries to launch the European training network TOMOCON (Smart Tomographic Sensors for Advanced Industrial Process Control). This platform will offer comprehensive doctoral training for a total of 15 junior researchers. The program is focused on developing new image-based measuring technologies to better control and regulate industrial processes. Thanks to ultrafast parallel data processing, they could act as sensors to control industrial facilities and machines in real time. Over the next four years, the European Union will support the international network to the tune of almost four million euros under its Marie Skłodowska-Curie Actions.


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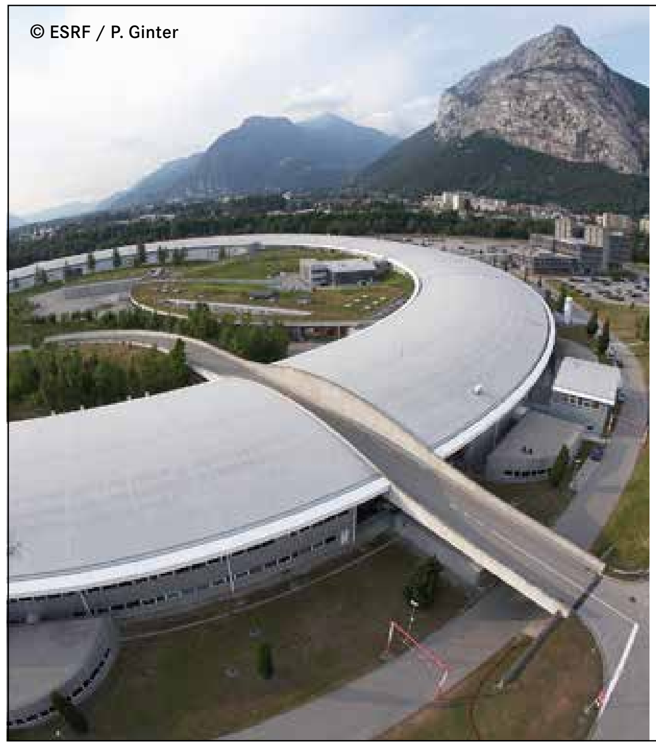
AGREED

French connection

In mid-October, HZDR and the French Laboratoire d'Optique Appliquée (LOA) signed a Memorandum of Understanding to intensify their scientific cooperation in the field of laser-particle acceleration. The two institutes will work together to advance the use of laser-based particle and radiation sources for medical applications, for instance in radiobiology or tumor therapy. During the initial five-year term of the memorandum, joint research projects as well as scientific staff exchanges will extend the institutes' collaboration. The École Polytechnique, the École Nationale Supérieure de Techniques Avancées, and the Centre National de la Recherche Scientifique jointly operate the Paris-based LOA.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ESTABLISHED

Great LEAPS for research

In mid-November, 16 research photon sources formed the new LEAPS consortium – the **L**eague of **E**uropean **A**ccelerator-based **P**hoton **S**ources. Its mission is to strengthen scientific exchange, facilitate more efficient access to the sources, and accelerate technological progress. Two basic types of photon sources are involved in the project: synchrotrons and free-electron lasers. Like universal super microscopes, both types of source allow us whole new, hitherto unattainable insights into the minutest details of the samples under examination.

↗ **www.leaps-initiative.eu**


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CAUSE FOR CELEBRATION

Happy birthday, HZDR!

To mark its 25th anniversary the research center held an annual reception and scientific symposium in mid-October. Many representatives of the political, industrial and research sectors joined in the celebrations. In her address, Saxony's Minister of Science Eva-Maria Stange hailed the research center's enormous achievements in the past quarter-century, such as the construction of three large-scale facilities that draw scientists from around the world, strong international collaborations, for instance with the Weizmann Institute of Science in Israel or the European Synchrotron in Grenoble, as well as numerous high-profile publications. At the reception, HZDR took the opportunity to thank its Administrative Director Peter Joehnk for more than 15 years of devoted service and wish him well on his retirement from the Board of Directors at the end of November.

WHAT'S ON

27 March 2018
FameLab Germany Dresden
Technische Sammlungen Dresden

09 June 2018, 10 a.m. - 4.30 p.m.
Open House Day
Helmholtz-Zentrum Dresden-Rossendorf

11 - 13 June 2018
2nd International HeFIB Conference
Institute of Ion Beam Physics and Materials Research

15 June 2018
Dresden Night of Sciences

20 June 2018
Freiberg Science Day

22 June 2018
Leipzig Night of Sciences

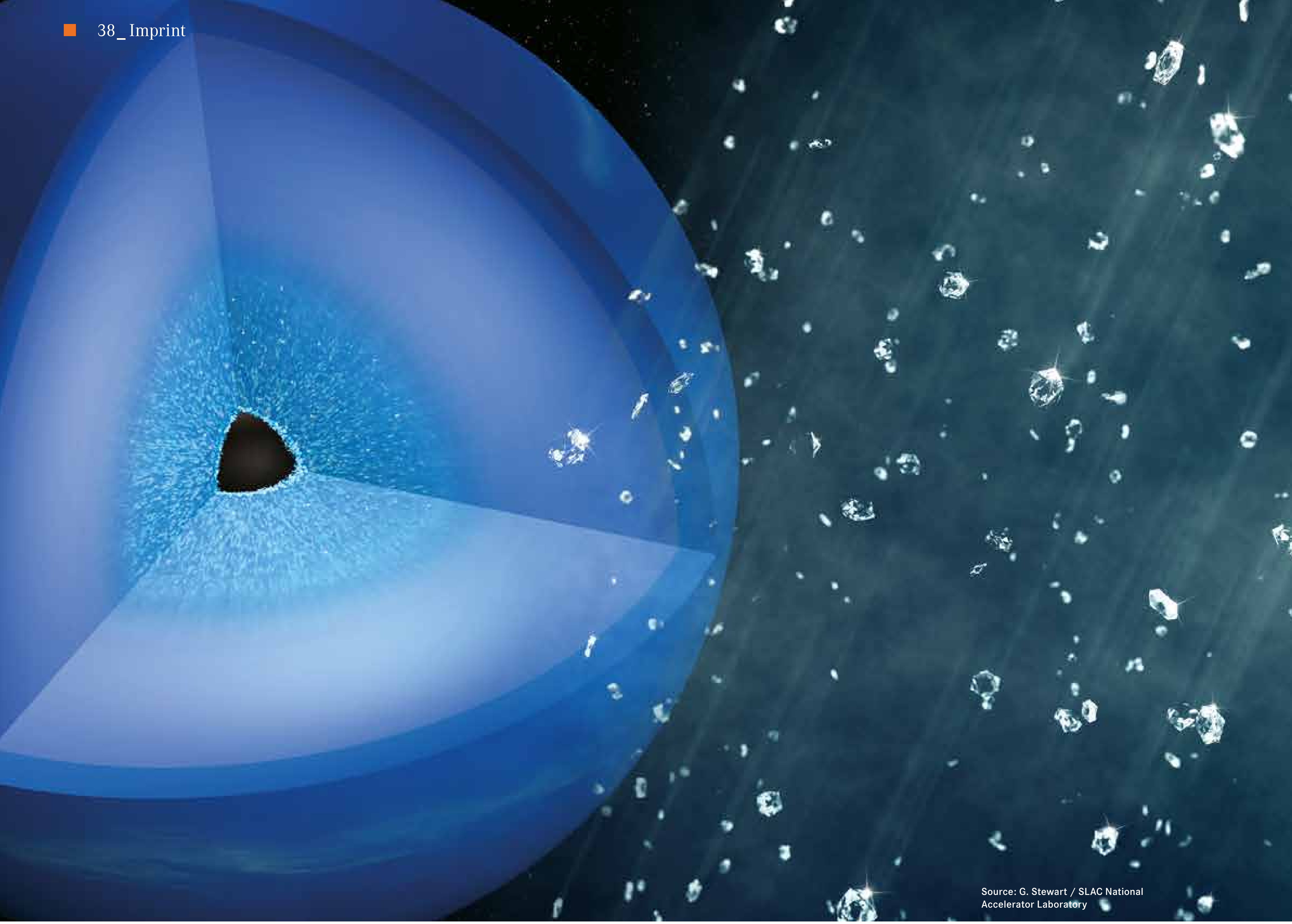
HONORED

Excellence in research ...

The Deutsche Physikalische Gesellschaft (DPG / German Physical Society) awarded in late November its Georg Simon Ohm Award to Toni Hache of the Westsächsische Hochschule Zwickau, University of Applied Sciences, for his outstanding Master's thesis in the field of nanotechnology, which he wrote at HZDR's Institute of Ion Beam Physics and Materials Research. The young scientist developed a nano-microwave oscillator based on the spin Hall effect, a component that efficiently converts direct currents into microwave oscillations. Modifiable frequencies, miniaturization, and low manufacturing cost make it a strong candidate for practical applications in communications technology and magnetic field sensor technology.

... and in training

Physics lab assistant Stefanie Sonntag scored 98 out of 100 possible points in her vocational certification exam – which makes her one of the best apprentices in her trade in the entire country. Sonntag, who had already been named 'Most Successful Physics Lab Assistant' by the Regional Chamber of Trade in Dresden and the Free State of Saxony, then received the 'Outstanding Performance Award' from the Conference of German Chambers of Industry and Trade in early December. HZDR is thus proud to have trained the best apprentice nationwide in this vocation for the second year in succession. The Saxon research center was also awarded the badge "Outstanding Achievement in Vocational Training" for the 18th consecutive time.



Source: G. Stewart / SLAC National Accelerator Laboratory

Neptune in the lab

When the high-intensity laser flashes meet the surface of the plastic sample it is transformed into a seething mélange in a split second. Thus excited, a shock wave races through the material, leaving very little behind – apart from nanometer-sized diamonds. Because they are so hard and extremely durable, businesses like to use these ultra-small treasures not only for electronic instruments and medical procedures but also as cutting materials in industrial manufacturing. Up to now, nanodiamonds have largely been produced in a complicated process of targeted blasting. Production using lasers could facilitate a process that is cleaner and easier to control.

An international team of researchers working with Dominik Kraus from HZDR's Institute of Radiation Physics recently had the opportunity to observe how plastic can be transformed into diamonds in real time. Using the Linac Coherent Light Source – one of the world's strongest X-ray laser sources – at the Stanford Linear Accelerator Center in California they were able to reconstruct the conditions in the interior of huge ice planets: extremely high temperatures and pressures. As the experiments demonstrated, this combination separates the compounds of hydrocarbons of which many plastic materials are composed. The carbon thus released subsequently turns into nanodiamonds.

In addition to new astrophysical insights into the composition of exoplanets, the researchers have now also been able to deliver information on a method which may, one day, make it easier to produce nanodiamonds.

PUBLISHED BY
Prof. Dr. Dr. h. c. Roland Sauerbrey and Dr. Ulrich Breuer, Board of Directors Helmholtz-Zentrum Dresden-Rossendorf (HZDR)

DATE OF PUBLICATION
January 2018
ISSN: 2194-5705 // Issue 02.2017

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LAYOUT
WERKSTATT X . Michael Voigt
www.werkstatt-x.de

PRINTING
Druckerei Mißbach
www.missbach.de

CIRCULATION
1,500 // Printed on Circlesilk (cover) and Circleoffset (content), FSC certified and awarded with the EU Ecolabel

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The HZDR research magazine “discovered” appears twice a year, also in German titled “entdeckt”.
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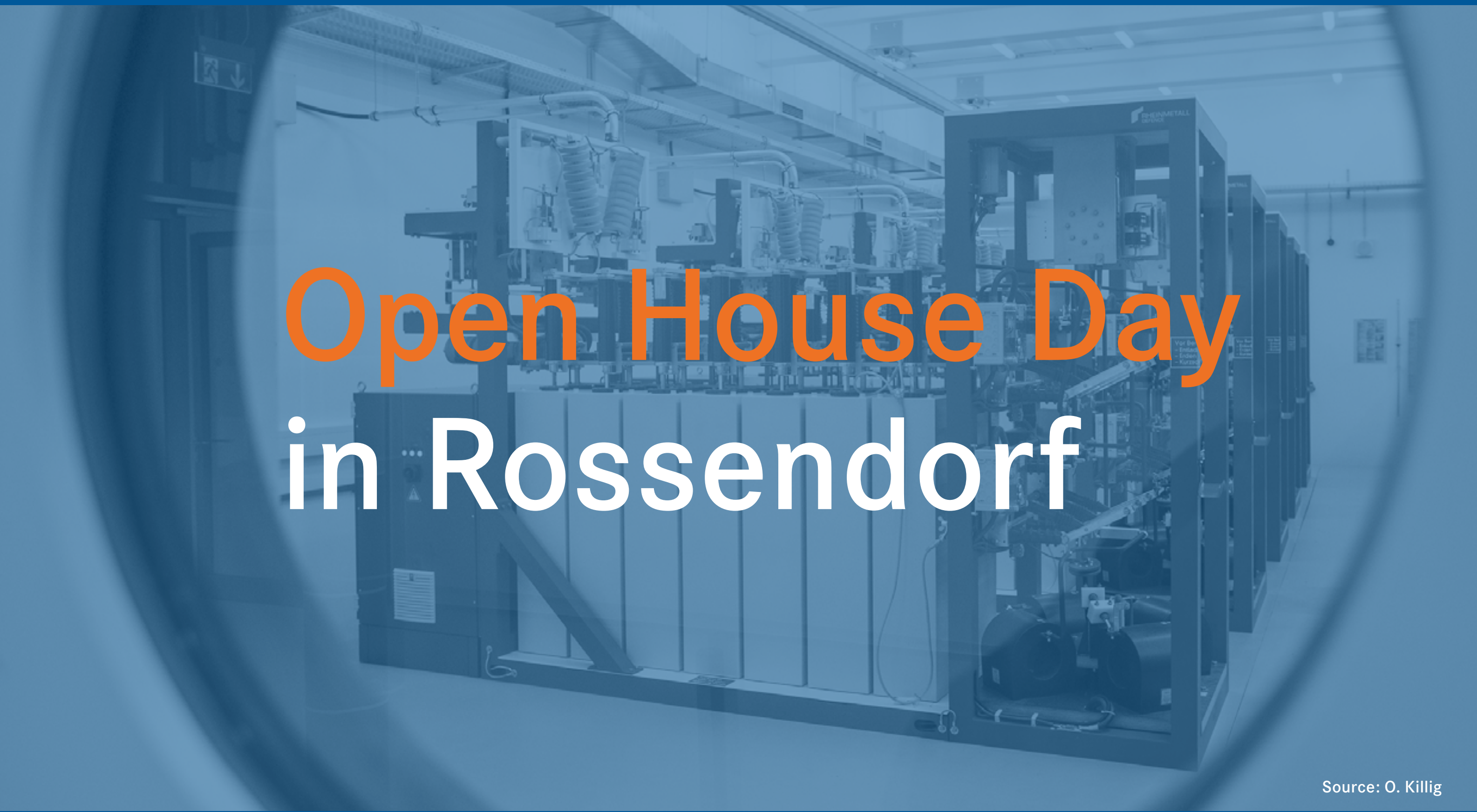
Open House Day in Rossendorf



Source: O. Killig

June 9

Sa | 10 am to 4.30 pm

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