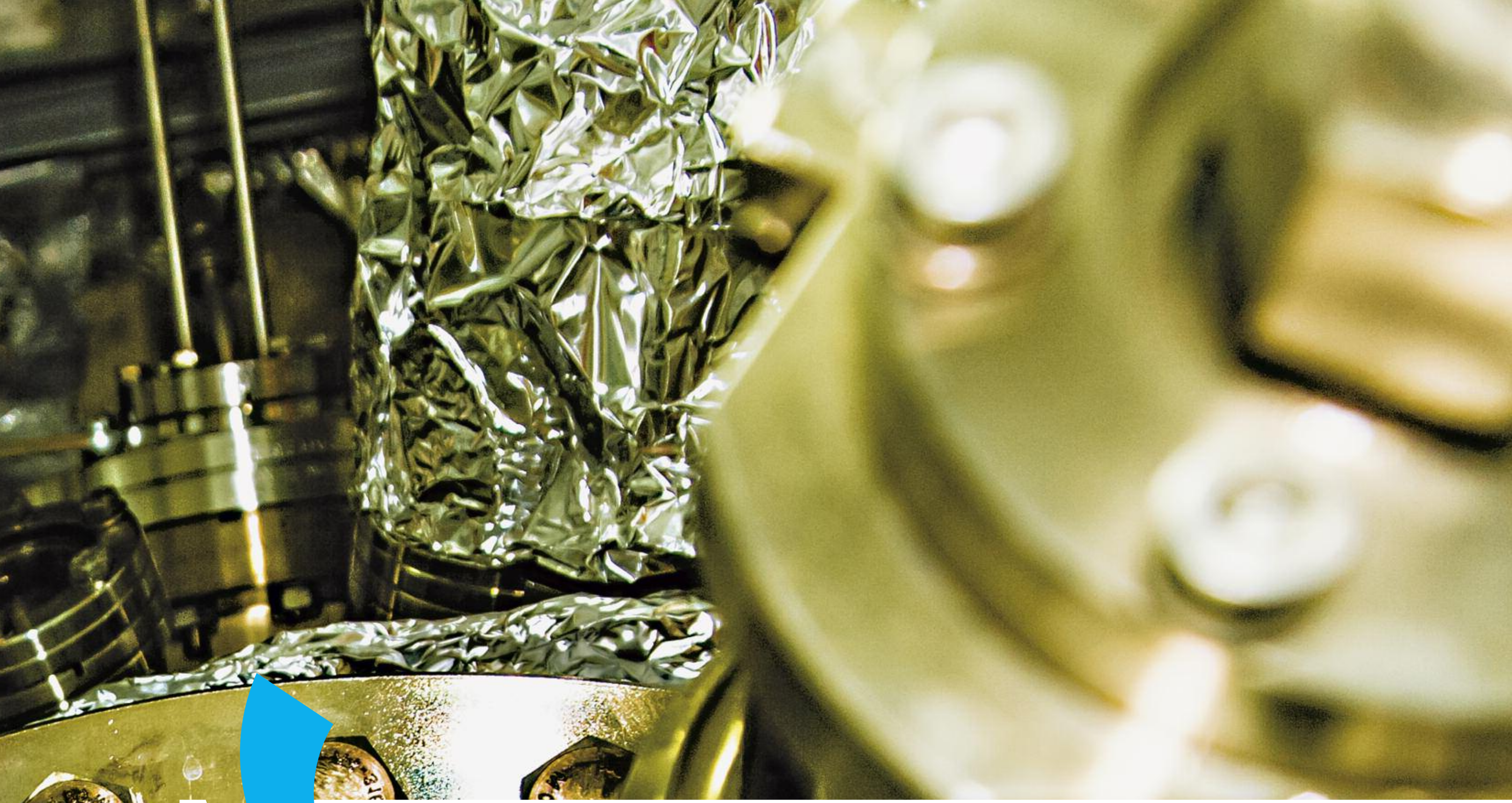
HZB Helmholtz Zentrum Berlin

FOCUSSING ENERGY REALISING VISIONS

HIGHLIGHTS 2012

Annual report with research highlights at the

Helmholtz-Zentrum Berlin für Materialien und Energie



CONTENTS

Foreword **04**
Interview: The future of energy research at HZB 06
BESSY II upgraded 08

Highlights from user experiments **10**
A catalyst with two faces 12
How clouds in the rainforest come from salt 13
Pocket hydrogen tanks 14
Storing data with salts 16
The Achilles heel of the malaria pathogen 18
Catalysts: greater power through defects 19
Finding faults in the cell building set 20

Highlights from our own research **22**
Sandwich-style magnetic valve 24
A close look at topological insulators 26
Making components out of graphene 28
Watching materials creep 30
Tell-tale asymmetry 31
X-ray view of lattice dynamycs 32
In a labyrinth of magnetic domains 33
Tailored organic semiconductors 34
Water as a door opener 35
Polysaccharide increases joint stability 36
Turbo for solar cells 37

Joint ventures **38**
Eye tumour therapy: Long-term outlook 39
Sunlight to hydrogen 40
PVcomB: Full capacity for small modules 41
Two new virtual institutes 42
New laboratory for liquids 42

Future projects **44**
Four measuring stations for EMIL 44
B*ERL*inPro: Breakthrough at the photoinjector 44
Record-setting magnet for neutron research 45

Miscellaneous **46**
Two new institutes at HZB 46
Prizes and awards 47
HZB gains two junior groups 48
Science photowalk and appointments 49

Appendix **50**
HZB Organisation Chart 50
Site map, imprint 51

HZB AT THE BEGINNING OF A NEW FUNDING PERIOD WITH THE FOCUS ON ENERGY RESEARCH

In spite of working every day with the large-scale research facilities, you never lose your respect for them", says Dr Silke Christiansen in the latest image film about the HZB energy research. She has been heading up the new institute Nano Architectures for Energy Conversion since the beginning of this year. Just as do most of the visitors to our centre, she also has a healthy respect for the seemingly inextricable labyrinth of leads, cables and connections that surround the numerous measuring stations and experimental stations at the BER II neutron source and the BESSY II electron storage ring. These designations stand for excellent instruments and experimenting facilities that are in part unique in the world. In 2012, a total of some 3000 scientists from home and abroad used these instruments for their research projects.


Prof. Dr. Anke Kaysser-Pyzalla and Thomas Frederking

The HZB staff who besides their own research, are in charge of the experimenting facilities and are constantly refining them, are preparing themselves at the moment for the upcoming appraisals. These appraisals will take place within the scope of the programme-oriented funding policy at Helmholtz Association in early 2014. We not only want to convince the examiners of the quality of the large facilities, the available measuring stations and the high level of our user service, but also that it makes good sense to invest in future large-scale projects relating to BESSY II and energy research.

Above all the project BESSY^{VSR} (Variable-pulse-length Storage Ring). With the planned upgrade of BESSY II that runs under this name, the idea is that users will in future be able to freely select the requisite pulse length of the photon beam at each individual beamline. They will then either use the familiar high brilliancy of a 3rd-generation storage ring or they can change over to a high repetition rate with short pulses of just a few picoseconds. The advantages are above all to be seen in the study of dynamic processes. For example, researchers could investigate the static properties of their samples with a high beam intensity and then use short light pulses to obtain complementary information about the time-resolved processes in the sample. Such a variability would be unique in the world. Seen in terms of the internationally available photon sources, it would be an ideal complement to the concept of a free electron laser which delivers extremely short pulses and diffraction-limited storage rings whose light is of maximum brilliance (read more on P. 8/9).

The EMIL project (Energy Materials In-Situ Laboratory) is progressing visibly. Once the excavators arrive in a few weeks, the project direct at the BESSY II storage ring will take on a tangible shape: a laboratory facility for researching into energy materials that has no equal anywhere in the world. In future, it is planned to use X-ray analysis to examine materials and processes used in photovoltaics as well as have groups from the Max-Planck Society analyse materials and mechanisms used in photocatalytic conversions. Once the extension to BESSY II is completed, one will be able to combine material manufacture with the ultra-precise analysis of layer properties like nowhere else in the world. The in-situ preparation permits the analysis of materials, structures and components in between individual preparation stages without having to interrupt the necessary ultrahigh- and high-vacuum conditions. At the same time, users will have a photon beam available which is characterised by an extremely wide energy range. This will make it possible to combine investigations into power generation, energy conversion and energy storage.

With the EMIL laboratory extension, it will also become visible to the outside exactly what has been happening inside HZB for a long time now: a stronger focus on research into the energy supply of the future. We are already among the leading locations in Europe with our thin-film technology on the sector of photovoltaics. And we would like to put this expertise on an even broader base in the future. One of the most crucial questions of the coming years will be how one can convert the electricity recovered by photovoltaic technology into storable sources of energy. It therefore pleases us immensely that we were able last year to not only appoint Prof. Silke Christiansen but also Prof. Dr. Roel van de Krol as head of the new institute Solar Fuels and Energy Storage Materials (read more on P.46.).

HZB scientists cooperate successfully with colleagues from universities, the partner institutes of the Helmholtz Association and other non-university institutions all over the world in solving a great many scientific questions. Besides joint research groups, HZB has also established joint labs which are ideally headed up by jointly appointed junior professors as an instrument aimed at facilitating the scientific cooperation with universities. In 2012, we were able in this way to open such a joint lab focused on "Investigation of liquids and functional materials in solution" together with the Freie Universität Berlin.

In the case of the two new virtual institutes which started up in 2012, we cooperate with a number of different partners. The examples shown on Page 42 illustrate clearly just why it is so important for HZB to work together with universities and other partners. Because in the final analysis, it is only cooperation that succeeds in pooling existing expertise and creating the ability to respond to scientific issues on a wider basis. Joint appointments enable the leading scientists from HZB to contribute their scientific results to university teaching and thus to inspire students for the world of research at HZB. And the universities make it possible for the young scientists to gather teaching experience and thus to improve their qualifications.

A volley of joint appointments for important university chairs was realised by HZB in 2012. Prof. Dr. Rutger Schlatmann, head of PVcomB, was awarded the chair for "Solar Cell Technology" at the Berlin University of Applied Sciences. It is the first joint appointment of HZB with this university. Prof. Dr. Bella Lake, head of the department "Quantum Phenomena in New Materials", was appointed to the TU Berlin, and Prof. Dr. Klaus Lips accepted the professorship for "Analytics for Photovoltaics" at the Freie Universität Berlin. Prof. Alan Tennant received an important distinction: the European Physical Society awarded him and five other international colleagues the prestigious Europhysics Prize for proving the existence of magnetic monopoles.

The numerous scientific articles which the users of BESSY II and BER II plus the staff of HZB have published speak volumes about the high research quality at HZB and the excellence of our large facility users. In the canon of the centre's research fields, it is photovoltaics, solar fuels and hydrogen storage materials that complement one another on the one hand, and magnetism, magnetic dynamics and high-performance data memories on the other. Extremely successful are also the research activities into a new material class, namely topological insulators, or the experiments on organic semiconductors. We would like to present these plus a selection of other HZB research results that are relevant to both society and science in this HZB Highlight Report 2012.

Prof. Dr. A. Kaysser-Pyzalla   Thomas Frederking

“WE WANT TO GET TO THE HIGH-HANGING FRUIT”

Finding a solution to humanity’s future energy supply is the foremost issue of our times. The need for research is staggering if we are ever going to be able to run the economic machine on renewable energies. HZB’s focus on “energy research” places it right at the centre of political discourse. An interview with **Prof. Dr. Bernd Rech** on how Germany’s planned energy turnaround affects strategies, cooperative research and everyday laboratory work.

Mr. Rech, you have been head of the Institute for Silicon Photovoltaics at HZB for a number of years and are the spokesman for solar energy research. How has the environment changed over this time?

I became head of the institute during the solar energy boom. Companies from the photovoltaics industry were growing and were greatly interested in cooperating with HZB. The focus then was on joint projects of basic research aimed at developing new products. This led to exciting cooperative efforts, and to the formation of PVcomB, the Photovoltaic Competence Centre Berlin.

It’s a more complex situation now: on the one hand, the German government has resolved to make the energy turnaround – so the changeover to renewable energies is set to happen in the long run. On the other hand, the solar industry is presently in a crisis. Still, a number of important companies we cooperate with have survived. This could at least be a sign that our research has contributed towards the innovative power of these companies.

Prof. Dr. Bernd Rech, head of the Institute for Silicon Photovoltaics at HZB and spokesman for solar energy research.

How must HZB’s solar energy research respond to this crisis?

In the short term, there is little we can do to help. We conduct long-term basic research – of course always with a view to real application. But photovoltaics is still in its infancy. If we consider the heat engine, as a comparison: it was invented three hundred years ago, made possible by industrialisation in the 19th century and, in highly evolved form, is a pillar of our modern economy. With photovoltaics, we are still right at the beginning of a developmental process that will probably last hundreds of years. That is why researchers must persevere, undeterred by any short-term fluctuations in the market or public funding choices. And the aim of this research is to make photovoltaics more efficient, cheaper to produce and, ideally, storable as well.

What does that mean in concrete terms?

The average photovoltaic system installed on the roof of a building has an efficiency of 15 percent. By contrast, physics tells us we could achieve as much as 80 percent. But storing solar energy efficiently, say by using it to produce hydrogen directly from water, is still a challenge. And we can’t make any real progress using classic laboratory methods here – we need entirely new tools that allow us to penetrate much deeper into matter. We must use these tools to analyse the physical laws at the atomic level and exploit them for real applications.

The energy supply is of great economic and social importance in all industrial nations – and an exciting field for research.

This is where the new project EMIL (Energy Materials In-situ Laboratory Berlin) comes in...

Exactly. EMIL will breathe new life into the electron synchrotron BESSY II for energy research. Modern laboratory methods will allow us to improve existing photovoltaic technologies and make them more efficient, but all the low-hanging fruit has been picked. We now want to get to the high-hanging fruit, which we can't even really see yet. EMIL will let us venture into the unknown. We will be using the planned lab complex to analyse the very atomic structure of solar cells and to develop new concepts for solar energy research. And by "we" I don't just mean HZB researchers, I mean solar energy researchers from everywhere in the world.

What does that mean in terms of work for the HZB researchers?

EMIL will become a central pillar of our future research. It is a big investment, which we can bring to life. As I said: we will be developing new research approaches, and I am confident the HZB institutes will work on new topics and open new doors. I am excited and I expect a lot to come from the fresh thinking and new ideas that our HZB scientists will certainly deliver. They are definitely up to the task: solar energy research is always materials research. It requires an understanding of the electrical, optical, structural and functional properties of materials that are promising for use in solar energy. We need to develop nanotech concepts in order to gain ideas for new components in photovoltaics and for storing solar energy. These are all topics that have already been touched upon at HZB – and which could provide the much-needed drive behind solar energy research.

The infrastructure project EMIL will create optimum conditions at the electron synchrotron BESSY II for researching into energy materials, Bernd Rech stresses. The new laboratory should be operational by 2015.

Isn't that a little over the top?

No. Our energy supply will definitely be one of the biggest issues of all time, and will demand great efforts from humanity over the coming decades. We need solutions to secure our future on this planet. HZB is tackling an important aspect of this, and society's expectations are high. What is positive is that we can look forward to exciting research projects for many years to come.

The interview was held by Hannes Schlender.

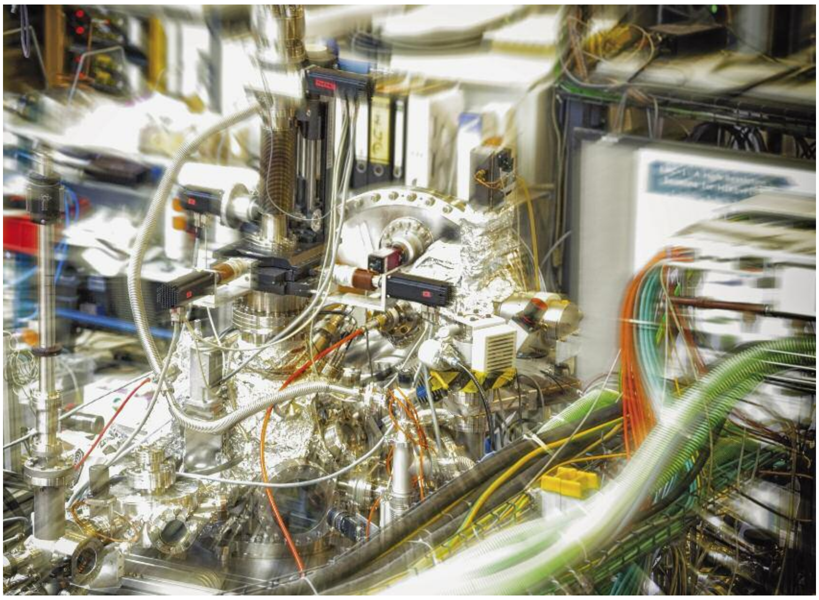
IN BRIEF

- While the energy turnaround is set to happen, companies in the solar branch are still fighting for survival.
- HZB conducts basic research that will improve the technological basis of solar energy in the long term.
- The aim of energy research at HZB is to make photovoltaics more efficient, cheaper and storable.
- With the EMIL project, the latest in laboratory methods is exploited for researching materials for producing solar cells.

BETTER RESEARCH AT BESSY II

Important upgrade projects make HZB's electron storage ring fit for the future.

The electron storage ring BESSY II in Adlershof went into operation as one of the first third-generation synchrotron sources nearly 15 years ago. The questions being pondered by its scientific users have since changed and, with it, their needs for specific photon beam properties. The challenge is to routinely improve the facility so that it remains attractive to users. The upgrade projects recently completed were more than merely routine improvements, though. The beam properties now achieved are an enormous advancement that will benefit more than 2,000 scientists researching at the facility each year.



Every year, more than 2,000 scientists work at the measuring stations with their elaborate instrumentation at the electron storage ring BESSY II in Berlin-Adlershof.

"What we did with the upgrade to BESSY II was open-heart surgery," says Prof. Dr. Andreas Jankowiak. Over the past two years, during ongoing operation and with only minimum loss of beam time for the users, the accelerator experts installed a new LINAC accelerator and modified numerous components in order to run the large facility in so-called top-up mode. The LINAC accelerator has been running since autumn 2012 and has ensured a practically constant intensity of photons ever since. "In top-up mode, it is very much easier to keep the entire machine in thermal equilibrium," Jankowiak explains. The beam must namely be guided to micrometre precision to compensate for even the tiniest thermal expansion.

As a complement to this upgrade, a "fast-orbit feedback" system (FOFB) now readjusts the electron beam 150 times a second so that users benefit from an extremely stable and precise photon beam. Were it not for the work of Dr. Peter Kuske, top-up could never have been implemented at BESSY, emphasizes Jankowiak, yet such a huge endeavour is always teamwork: the experts from the Accelerator Group and from the Undulator, Radiation Protection and Infrastructure Departments all made crucial contributions.

Outlook: BESSY^{VSR}

If a large facility is to stay at the forefront over several decades, then its very design must be continually revamped. BESSY II already has a major advantage in that the facility can be operated in a second mode that delivers substantially shorter photon pulses. Researchers need short pulses to study dynamic processes in samples, for instance. At present, however, researchers at BESSY II can only choose one mode or the other – that is either a high photon flux or short pulses. The latter have only ever been produced a few days a year so far.

The idea now is to offer variable pulse lengths at BESSY II. This is an entirely new concept, which goes by the name BESSY^{VSR} (Variable-pulse-length Storage Ring). Essentially, the idea is for users to be able to freely choose the pulse length for each experiment at each individual beamline.

As part of an upgrade to BESSY II, this facility for the highly stable magnet power supply to the BESSY-II storage ring was also installed.

This would allow them, for example, to illuminate a sample at high intensity first, and then obtain complementary information on time-resolved processes in the sample using short pulses. "The variability we are looking to achieve with BESSY^{VSR} would be unique in the world," says Professor Dr. Alexander Föhlisch, head of the institute "Methods and Instrumentation for Synchrotron Radiation Research". While other concepts attempt to increase the brilliancy ("ultimate storage ring") or are designed for extremely short pulses ("free electron laser"), BESSY^{VSR} may soon be favoured among users for offering unrivalled flexibility in pulse length.

"We have begun a design study for BESSY^{VSR}," Andreas Jankowiak reports. BESSY II already offers pulses of about two picoseconds when operated in "low-alpha mode" but, as it stands, the intensity has to be reduced in order to minimise interference effects. This mode is therefore not suitable for all questions in research.

Double benefit from *BERL*inPro

"Scientists already formulated the idea years ago of generating short pulses using new cavity resonators that can produce much greater acceleration gradients than those currently employed at BESSY II," Jankowiak explains. At present, there are four cavity resonators inside which the electrons absorb energy, each operating at a frequency of 500 megahertz and a voltage of 400 kilovolts. "Our calculations show that, with novel cavity resonators operating at frequencies of 1.5 and 1.75 gigahertz and a total of about 45 million volts, we could produce variable pulse lengths from 1.5 to 15 picoseconds at full intensity." The cavity resonators required for this, however, would have to be built out of superconducting niobium and operated at temperatures of around two kelvin. They would also have to be able to accelerate the high currents in a storage ring without interference effects.

When BESSY^{VSR} was first conceived, such cavities were still a technical hurdle. With the future project BERLinPro, however, the situation has changed. "The exact same kind of resonators were also needed for BERLinPro. The developmental work which has already begun therefore pays off twice. We will conduct the design study until 2014, so that we can continue with the implementation after that," Andreas Jankowiak declares.

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TOP-UP MODE AT BESSY II

BESSY II is Germany's leading third-generation synchrotron source concentrating on the soft X-ray region. It draws around 2,000 scientists from Germany and abroad each year, who appreciate the outstanding reliability and stability of the large facility. On more than 50 experimental stations (beamlines), researchers can adjust the wavelength, direction of oscillation (polarisation) and energy of the photons.

Up until the autumn of 2012, new electrons were shot into the storage ring every eight hours to balance out the losses. Now, in so-called "top-up" mode, electron packets can be reinjected every 30 to 60 seconds during operation. This was made possible by installing a new LINAC-type preaccelerator. Also, the beam guidance is now corrected 150 times a second using fast-orbit feedback. These measures improve the stability of the sensitive X-ray optics and ensure a near-constant light intensity for the experimenters. HZB's experts are continually making such upgrades to the large facility.

HIGHLIGHTS FROM USER EXPERIMENTS

2,970 user visits to the electron storage ring BESSY II in Berlin-Adlershof were recorded in 2012, working in 494 research groups from 31 countries.

26,775 eight-hour shifts were available in 2012 at the 39 beam tubes and experimental stations at BESSY II. Of these, 14,200 shifts were available for experiments. 12,575 shifts were used for extensive maintenance and upgrade work.

9,270 eight-hour shifts were used by external researchers at BESSY II. Another 2,101 shifts were used for internal experiments of HZB scientists. 2,829 shifts were used for commissioning, i.e. setting up the individual instruments for the respective experiments.

152 days with eight reactor cycles was how long the neutron source BER II in Berlin-Wannsee was in powered operation last year after coming back online at the end of March 2012. This equates to 1,672 instrument days available at the eleven instruments. Of these, 441 days were required for maintenance and instrumentation and 177 days for continuing upgrade work. 1,054 instrument days were available for experiments.

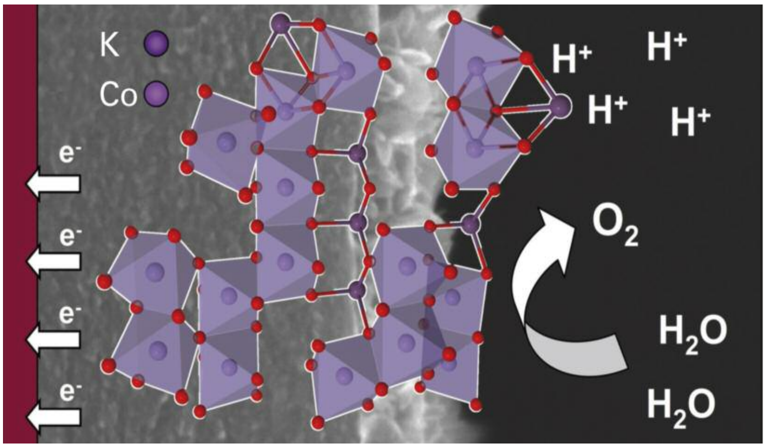
75 percent of the 1,054 instrument days at BER II were used for short-term projects and 2 percent for long-term projects of cooperative partners. Another 23 percent of instrument days were used for in-house research by HZB scientists.

235 cooperatives with other scientific establishments were hosted at HZB at the end of 2012. Of these, 152 were for research with photons, neutrons and ions (PNI), and 83 for renewable energies (RE).

A CATALYST WITH TWO FACES

An international research group led by Holger Dau of the Freie Universität Berlin has studied a **cobalt-based catalyst** that supports both oxygen and hydrogen formation. It could be used to chemically store solar energy on a large scale.

One of the problems of generating power from the sun and wind is that it often delivers far more electricity than is needed at the time. Then there are other times when not enough power is generated, such as during the night or when no wind is blowing. A solution to this dilemma is to use the excess electricity to split water electrolytically into oxygen and hydrogen. Hydrogen namely makes an excellent chemical energy store or fuel, or can be used in a fuel cell to produce electricity. The chemical reaction to achieve this, however, has a serious disadvantage: without expensive catalysts made from platinum, iridium or ruthenium, too much energy is given off as heat and is accordingly wasted. "If we wanted to store energy at a globally relevant scale using this technology, we would fail due to the scarceness of these rare chemical elements alone," explains Prof. Dr. Holger Dau of FU Berlin. Within the cluster of excellence Unifying Concepts in Catalysis (UNICAT), the biophysicist and his colleagues are studying novel catalysts that require no precious metals to accelerate the desired reactions.



By applying a negative voltage, a solution of cobalt, potassium and phosphate (violet-red) forms a layer on the electrode (grey) that acts as a catalyst to accelerate the splitting of water into oxygen and hydrogen.

Voltage changes the direction of reaction

Just recently, they made a surprising discovery. They were studying how, in a solution of cobalt, potassium and phosphate compounds, a catalyst layer would essentially form by itself on the electrode. This process was first described in 2008 by American chemist Dan Nocera of MIT and has since been a promising path towards developing low-cost catalysts. Nocera observed a phosphate-containing cobalt oxide (O_2-CoCat) layer forming on the positively charged electrode, where it accelerated the formation of oxygen. "We have now shown that it works in reverse," Holger Dau reports. They used the same solution, but applied a negative voltage instead of a positive voltage. What they observed astonished them: within minutes, a coat had formed that accelerated hydrogen formation as a catalyst: H_2-CoCat. "We then applied a positive voltage again and actually observed how the catalyst converted back into the amorphous cobalt oxide film O_2-CoCat that Nocera had described earlier." The reaction can be repeatedly reversed.
At BESSY II, together with colleagues from CEA and UDF, Grenoble, Dau studied the Co-Cat-coated electrodes using the KMC1 experiment they developed, which gives them a look at the atomic structure of the layers. Both catalysts were structurally similar: Out of the solution, robust nanoparticles of cobalt oxides deposit onto the oxygen-generating positive electrode or – when the polarity is reversed – cobalt hydroxide particles deposit onto the hydrogen-generating negative electrode.

Set-up of a permanent experiment KMC3

While the layers of nanoparticles appear quite homogeneous under the electron microscope, the analysis at BESSY II revealed that, at the atomic scale, they are completely unordered. The cobalt atoms are joined together by oxygen atoms and probably stack up in loose layers. The intermediate spaces are filled with water in which phos-

phate salts are dissolved. Such a structure of unordered fragments could well explain the catalytic properties: The active surface in this structure is very large and the trapped water allows rapid ion transport.
Starting from autumn 2013, Dau and his team, with the help of Prof. Dr. Alexej Erko, will install the follow-up experiment KMC3 at BESSY II. It will not need to be constantly built up and dismantled, rather will remain in place to be available to other users. Then they will test whether and how the ultimate objective can be achieved: a simple technical system of one solar cell whose power feeds two electrodes that automatically coat themselves with the appropriate catalysts. Then, Nocera's ambitious vision could come true, where every household will soon be powered by its own solar energy source and hydrogen store. *arö*

Nature Mater. 11, 802-7 (2012), (DOI:10.1038/nmat3385): A Janus cobalt-based catalytic material for electro-splitting of water, Cobo et al

HOW CLOUDS IN THE RAINFOREST COME FROM SALT

Researchers from MPIC working at HZB have worked out how plants influence the **formation of fog and clouds** in the rainforest. This could help us make better estimates of the human influence on climate change.

The creation of fog and clouds constitutes natural phenomena that researchers have long understood. They form when the air contains fine aerosol particles on which moisture condenses. Soot and dust can serve as condensation nuclei in cities, for instance. So, what about places like the Amazon rainforest? Researchers had long assumed that most aerosol particles above the forest consist of purely organic material and are formed by chemical reactions of gas molecules in the atmosphere. Climate researchers are greatly interested in the Amazon because it represents an ecosystem largely untouched by man where the preindustrial state of nature can be studied.
PhD student Christopher Pöhlker from the group of Dr. Ulrich Pöschl and Prof. Dr. Meinrat O. Andreae at the Max Planck Institute for Chemistry in Mainz studied organic aerosol particles at BESSY II of Helmholtz-Zentrum Berlin that were collected on air filters and wafer-thin plates in the untouched Brazilian rainforest north of Manaus. He made an astonishing discovery: “We found three kinds of organic aerosol particles and all of them contained potassium salts,” reports Christopher Pöhlker. “At first we had focussed on the carbon, oxygen and nitrogen content of the organic material. But then, to our surprise, we also discovered very high potassium contents of up to 20 percent,” the chemist adds. This discovery was made using a new aerosol analysis method which Pöhlker and other researchers performed on the X-ray microscope MAXYMUS at BESSY II of HZB and at the synchrotron light source of the Lawrence Berkeley National Laboratory in California.
The potassium is released by fungi and other plants in the rainforest, although it is still unknown as to why they release these low-volatility, inorganic salts. The tiny potassium salt particles apparently form the core of the cloud condensation nuclei in the rainforest, and thus influence cloud formation and precipitation. The results help to identify and quantify the sources and the influence of organic aerosol particles. This, in turn, is important for understanding their interplay with clouds and precipitation in the natural climate system of the rainforest. The researchers believe this will allow them to make better estimates of the influence of human activities on global climate change.
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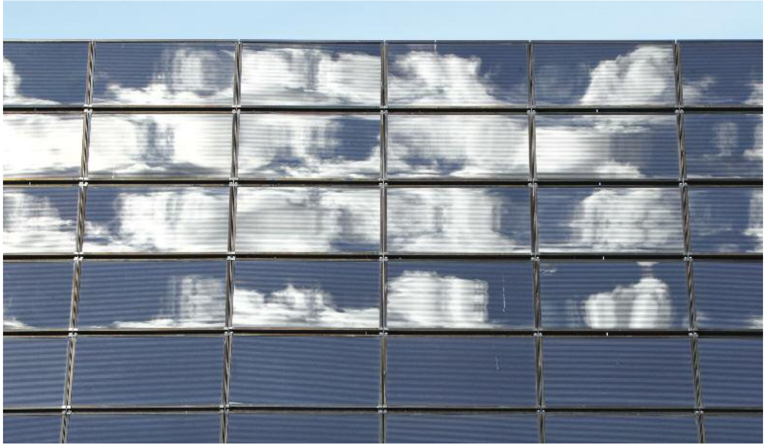
Organic substances condense onto potassium salts from fungi and plants, creating aerosol particles. Fog and cloud droplets form around these in the rainforest.

Science: Vol. 337 no. 6098 pp. 1075-1078 (DOI: 10.1126/science.1223264): Biogenic potassium salt particles as seeds for secondary organic aerosol in the Amazon, C. Pöhlker, K. T. Wiedemann, B. Sinha, M. Shiraiwa, S. S. Gunthe, M. Smith, H. Su, P. Artaxo, Q. Chen, Y. Cheng, W. Elbert, M. K. Gilles, A. L. D Kilcoyne, R. C. Moffet, M. Weigand, S. T. Martin, U. Pöschl, M. O. Andreae

POCKET HYDROGEN TANKS

An international research group has used neutron beams to study **magnesium alloys as a potential storage medium** for hydrogen.

If you ask a scientist what is the ideal energy store, the likely reply will be "hydrogen". A fuel-cell-powered vehicle, for instance, will travel more than five times further on one kilogram of this lightest of all elements than a modern, middle-class car will travel on petrol or diesel. And one gram of hydrogen in a laptop or mobile phone will yield far more hours of operation than a present-day battery. What is more, hydrogen can be produced in a relatively simple reaction using electricity from wind turbines or solar power plants. The only resource consumed is water, which is abundant on earth. When combusted or consumed in a fuel cell, the very water from which the hydrogen was obtained is created again. Helmut Fritzsche of Chalk River Laboratories in Ontario, Canada, and Dr. Roland Steitz of Helmholtz-Zentrum Berlin are researching all the possibilities of hydrogen storage to make good use of this eco-friendly and sustainable energy supply.



Solar power plants only deliver energy when the sun shines. If we are to use this energy some time later as well, we first have to store it. HZB is researching intensively on practical methods for storing this energy in the form of hydrogen.

Hybrid solution to fit in your pocket

The biggest problem encountered so far is that hydrogen is a very light gas. In its normal state, five kilograms would fit into a gas tank of more than fifty thousand litres in volume. This would of course be much bigger than the middle-class car it is supposed to fuel over a range of 500 kilometres. Automakers therefore use tanks in which the gas is compressed to 700 bar pressure. But this solution could hardly make a suitable energy store for mobile phones and laptops. After all, who would want to carry a phone around in their pocket with such a highly pressurised mini-tank? Scientists around the world are accordingly looking for ways to store the gas in solid state. One of the successful solutions is to use metals or alloys that rapidly form a chemical bond with hydrogen, socalled hydrides. Helmut Fritzsche is particularly interested in the light metal magnesium for this application. One gram of magnesium hydride namely contains 7.6 percent or 76 milligrams of hydrogen and therefore stores a lot of energy at low weight. This sounds promising. To boot, there are large quantities of magnesium worldwide, so price should hardly be a problem either.

Nevertheless, certain serious problems arise in its practical implementation. For example, magnesium only absorbs hydrogen quickly and releases it at a useful rate again when heated to relatively high temperatures of around 300 degrees Celsius. Charging in a normal climate would therefore take forever, after which the material would hardly release the stored hydrogen at all anyway. Not exactly how we imagine the ideal energy store.

BER II makes hydrogen visible

Naturally, scientists know of many ways to overcome such hurdles. Catalysts, for example, accelerate chemical reactions such as those that create hydrides, and steer them towards low temperatures when charging. If the researchers substituted pure magnesium with an alloy containing an additional ten percent chromium and ten percent vanadium, then the hydrogen might distribute itself more rapidly, and

the charging time would become shorter still. This also works apparently when other metals such as aluminium are added. In order to understand and improve such possibilities, the researchers are looking to fully understand how these additives and catalysts work. This is where the neutrons from the neutron source BER II of HZB come in.
"The neutron beams, so to say, make the hydrogen in the system visible," Roland Steitz explains the principle. In order to observe the processes, the researchers build the mini model of a hydrogen tank out of magnesium or an alloy of magnesium and other metals, which is barely 50 millionths of a millimetre thick. On top of this comes a layer of the proven yet prohibitively expensive catalyst palladium that is five millionths of a millimetre thick, as well as an equally thick layer of other metals such as chromium and vanadium, or even tantalum, nickel or titanium. "This additional metal layer prevents the palladium from wandering into the magnesium alloy below," explains Helmut Fritzsche.

With the reflectometer (V6) at the neutron source BER II, the scientists gained insights into the structure of the magnesium alloys.

Charging process studied in detail

Just as a bathroom mirror reflects light rays at the same angle as they strike it, the atoms in this mini energy store deflect a neutron beam. As the researchers rotate the sample, the direction in which the neutrons scatter also changes. As hydrogen then flows into the store, the affected regions reflect the neutrons differently from before. By following this change, the researchers can observe how the hydrogen behaves in the individual layers. That means they can observe every single phase of charging and any problems that might arise during the process. In nature, hydrogen occurs in both a light and a heavy variant, called deuterium. Because the heavier deuterium scatters neutrons much more widely than its lighter twin hydrogen, the researchers introduce the more easily observed deuterium into the mini storage system.
After a number of calculations, the scientists have a much better understanding of how magnesium absorbs the hydrogen or deuterium. The catalyst palladium on the very top splits the hydrogen molecules, normally comprising two atoms, into its individual constituents. This produces "hydrogen radicals", which are swifter and therefore penetrate faster into the magnesium layers of the tank. Yet they are also considerably faster to react with the metal than the more sedate hydrogen molecules. "As a result, a layer of magnesium hydroxide forms rapidly on the surface, blocking or at least greatly slowing down the further penetration of radicals," Roland Steitz explains.

This barrier of magnesium hydride does not form, however, if the store itself is made of a magnesium-chromium-vanadium alloy. Such results have put the researchers on the track towards better magnesium stores that absorb and release hydrogen more rapidly or at lower temperatures. Furthermore, using similar experiments, Roland Steitz and Helmut Fritzsche understand the workings of a hydrogen tank made of 70 percent magnesium and 30 percent aluminium. They can also look for cheaper catalysts that, like the expensive palladium, break the hydrogen molecules into radicals that subsequently fill the energy store. Using such refined experiments, the researchers are taking important steps towards new hydrogen stores. *rk*

J. Phys. Chem. C 2012, 116 9), pp 5868–5880 (DOI: 10.1021/jp209296b): Probing the Room Temperature Deuterium Absorption Kinetics in Nanoscale Magnesium based Hydrogen Storage Multilayers using Neutron Reflectometry, X-ray Diffraction and Atomic Force Microscopy; W.P. Kalisvaart, E.J. Luber, E. Poirier, C.T. Harrower, A. Teichert, D. Wallacher, N. Grimm, R. Steitz, H. Fritzsche and D. Mitlin

IN BRIEF

- Hydrogen is an ideal energy store, but it takes up far too much volume for many applications.
- Magnesium can absorb a lot of hydrogen in a small volume – but only at high temperatures.
- Magnesium alloys could solve the problem, but how they work had always been unclear.
- Using neutrons from the neutron source BER II, scientists have studied how such alloys absorb and release hydrogen.

STORING DATA WITH SALTS

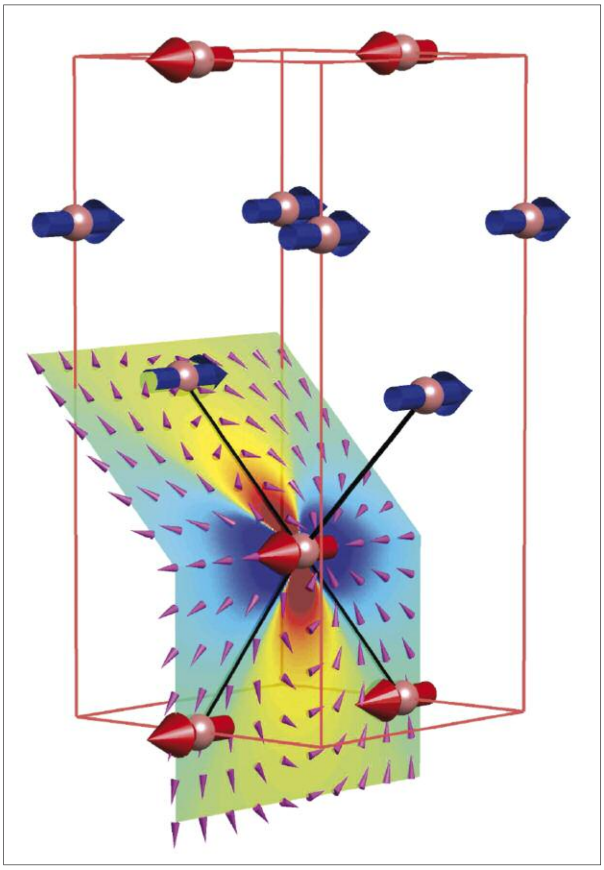
Some salts exhibit a surprisingly magnetic behaviour, making them highly sought-after materials for **fundamental quantum physics experiments** – and raise new hopes for novel high-capacity storage media.

Magnetic phenomena are at the heart of many technologies: magnetic fields are used to convert mechanical energy into electrical energy in gas-fired power plants and wind turbines, for instance. It is the reverse in electric motors, where they convert electricity into motion. Magnetisable materials on computer hard disks store data that can be written, read or deleted by a magnetic field. Yet despite its widespread use, there are still many fundamental questions about magnetism to which we do not have a full answer. Nowhere is this more so than at the atomic scale, where quantum effects reign. An international group of scientists from Switzerland and Great Britain, together with researchers from HZB, has now discovered a material that possesses surprising magnetic properties. It is a compound of lithium, the rare earth metal erbium and fluorine. This pale pink salt turned out to be an ideal substance for analysing magnetic processes and even exploiting them for technical applications. The compound, of chemical formula $LiErF_4$, opens up promising new avenues for developing novel, ultra-high density and long-lived data storage media.

Two methods are better than one

The researchers from the Laboratory for Quantum Magnetism of the École Polytechnique Fédérale (EPFL) in Lausanne and the London Centre for Nanotechnology used various experimental facilities at HZB for their study. The Berlin research centre namely offers unique opportunities for precise measurement of the inner structure and magnetic properties of crystalline materials.

$LiErF_4$ has no outwardly acting magnetic field, but its internal structure is governed by magnetic effects. The salt has a magnetic configuration that physicists call antiferromagnetism: the atoms in the salt and their spins – a quantum mechanical property that lends every atom a weak magnetic field similar to the field of a rod magnet – align in such a way that pairs of atomic magnetic fields cancel each other out. Antiferromagnetic materials differ in this respect from ferromagnets such as iron, in which the spins are aligned in parallel and add up to a detectable magnetic field.



Pictured is the antiferromagnetic arrangement of spins in the material $LiErF_4$. The researchers discovered this arrangement with the help of neutron scattering at the Berlin neutron source BER II.

To ascertain the structure of the material, the scientists studied it in two ways: by measuring the specific heat capacity and by measuring the diffraction of a neutron beam. The researchers performed the heat capacity measurements at the Laboratory for Magnetic Measurements (LaMMB) at HZB, and used the Berlin neutron source BER II for their diffraction experiments. “This combination of two complementary measuring techniques was crucial for the significance of the experimental results," says Dr. Bastian Klemke, researcher at the HZB Institute for Complex Magnetic Materials. Another advantage of the diverse experimental facilities in Berlin is that highly sensitive analyses can be performed here at very low temperatures and in strong magnetic fields at the same time.

Phase change at ultra-low temperatures

In order to rule out interference from thermal motion of the atoms, the researchers cooled the samples down to about 80 millikelvins – 80 thousandths of a degree above the absolute zero point of minus 273.15 degrees Celsius. Under these conditions, they carefully varied the temperature in tiny steps. At the same time, a magnetic field was applied to the probe, which the researchers also varied. For each value of these experimental variables, they precisely measured the heat capacity of the material. The team observed a striking phase transition at a specific temperature and magnetic field strength; the substance changed its properties drastically at this critical point.

The neutron diffraction measurements confirmed this finding and also allowed a detailed look at the atomic arrangement inside the crystal. Below a temperature of around 370 millikelvins, a two-dimensional magnetic structure evolved in the salt. "The material behaves as though it consists of an extremely thin layer formed out of a single layer of atoms only," says Klemke – even though the samples were in reality much thicker. It appears that various quantum mechanical interactions cause the spins with their magnetic moments to couple into close-lying, monoatomic layers. The characteristics of these layers become steadfast and dominate the behaviour of the crystal – to the scientists' surprise.

They now intend to find out in further experiments how this unusual coupling occurs in the material. "Similar substances from the same class of materials are being studied in new experiments that began at HZB in April 2013," Klemke reports. This includes other lithium fluorides that contain a different rare earth metal instead of erbium.

Miniaturisation of data storage media

Their surprising magnetic properties make these kinds of salts a perfect model for studying fundamental quantum mechanical phenomena. At the same time, they could also become the basis for certain IT applications – for instance as a building material for hard disks that can pack immense quantities of data into a tiny amount of space. Hard disks are based on magnetizable materials divided into small areas – called domains – where the magnetisation can point in two different directions. This can be used to represent digital bits as ones and zeroes imprinted in the material.

In order to pack more data into such a storage medium, its domains have to be shrunk down. This has already happened many times over as microelectronics have been

For researching $LiErF_4$, the scientists used various equipment and methods that were only available at HZB in this combination.

miniaturised over the years. Yet continual shrinking of conventional hard disks is running into an increasing number of problems. As the tiny memory bits are being pushed ever closer together, their influence on one another is increasing. One will cause changes in the other's magnetisation, causing the stored data to be lost. If we were to use antiferromagnetic fluoride salts, however, we could continue this miniaturisation without any problems. Ultimately, the bits would be so small that they would comprise only a single pair of atoms of opposite magnetisation. The amount of data that could be stored in such a medium would be humungous. And the stored data would remain intact practically indefinitely, since the bits would never interfere with one another. *rb*

Science 336 (6087): 1416-9, 2012, (DOI:10.1126/science.1221878): Dipolar antiferromagnetism and quantum criticality in $LiErF_4$; C. Kraemer, N. Nikseresht, J.O. Piatek, N. Tsyrulin, B. Dalla Piazza, K. Kiefer, B. Klemke, T.F. Rosenbaum, G. Aeppli, C. Gannarelli, K. Prokes, A. Podlesnyak, T. Strässle, L. Keller, O. Zaharko, K.W. Krämer, H.M. Rønnow

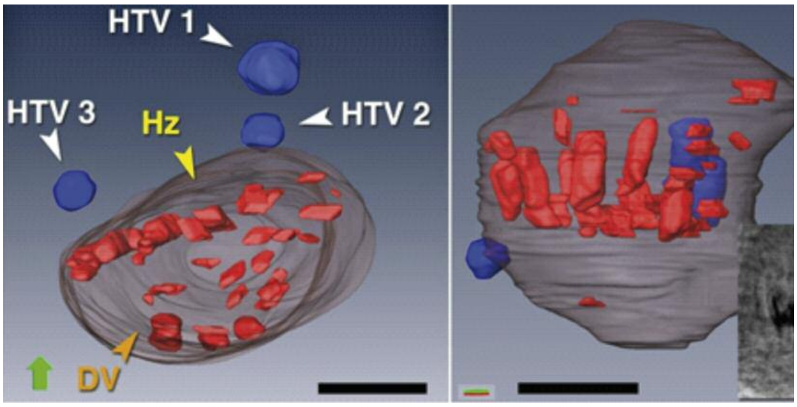
IN BRIEF

- Magnetisable materials are key ingredients in data storage media.
- A salt of lithium, erbium and fluoride possesses surprising magnetic properties that make it an ideal miniature data storage medium.
- An international research team analysed the salt using various methods at HZB.
- The results prove a quantum mechanical effect is the cause for its behaviour.
- Further research is needed to lay the basis for technical serviceability.

THE ACHILLES HEEL OF THE MALARIA PATHOGEN

Scientists of the Israeli Weizman Institute studied the **malaria pathogen plasmodium** at HZB. Their results could help effectively combat the disease.

Thankfully, even dangerous parasites and pathogens have an "Achilles heel". These are the weak points that most medications attack when doctors treat or prevent the diseases they cause. In the pathogens of the genus of plasmodia, which causes the world's most widespread tropical disease malaria, this weak point is called "haem". It is the iron-containing part of blood on which the single-celled pathogens feed in both the mosquito and man. Yet haem is highly toxic already and actually ought to kill the pathogen on its own. Instead, plasmodia join multiple haem mol-ecules into bigger units, thus detoxifying them. Researchers from the Weizman Institute, Israel, studied this process in detail using an X-ray microscope at HZB.



Soft X-rays at BESSY II were used to determine the arrangement of the haemozoin crystals (Hz, red) inside the digestive vacuole (DV) of the malaria pathogen.

Drugs against malaria such as the natural medicine "quinine" derived from the cinchona shrub, have been used by the Quechua people in Peru for many centuries. The Jesuits brought it to Europe and performed the first successful treatment of malaria patients with it in Rome in 1631. Later, the very similar drugs chloroquine and mefloquine were to follow. These substances worked excellently, at first. Over time, however, a number of plasmodia must have developed resistances to these drugs, for there are now strains of the pathogen on which they have no effect.

Understanding and improving the action of drugs

If we are to develop better drugs against malaria, medical professionals and researchers must first understand how quinine and co. actually work. All we know so far is that the drug apparently disrupts plasmodia's detoxification reaction that joins the iron-containing molecules into a compound called "haemozoin", which is no longer toxic and can therefore be stored inside the single-celled organism. To learn more about this process, the researchers of the Weizman Institute took a look inside some plasmodia. "We can do this especially well using the soft X-rays of half a kilo-electron volt energy from the synchrotron source BESSY II," reports Gerd Schneider of HZB. "Within this energy range, there namely exists what we call a water window in which the X-rays look straight through the water inside the cell," the physicist explains. Yet the X-rays reveal other important elements in living organisms such as carbon or nitrogen in rich contrast.

The researchers therefore saw the cell structures very clearly and were able to observe where haemozoin forms inside the plasmodium. As expected, it takes place inside a tiny organelle of the pathogen which biologists refer to as a "digestive vacuole". "But it's an intriguing question as to whether this happens in a watery environment or rather inside tiny fat droplets," Gerd Schneider continues. This information is important for manufacturing drugs, since their action is greatly influenced by this environment. Using the Berlin X-ray microscope, the researchers discovered that the crystals form within the aqueous areas of the digestive vacuole. They can now take a closer look at the action of malaria drugs in this setting in further experiments. It may just take them another step forward in the fight against malaria. *rk*

PNAS (doi: 10.1073/pnas.1118120109): Oriented nucleation of hemozoin at the digestive vacuole membrane in Plasmodium falciparum; S. Kapishnikov, A. Weiner, E. Shimoni, P. Guttmann, G. Schneider, N. Dahan-Pasternak, R. Dzikowski, L. Leiserowitz and M. Elbaum

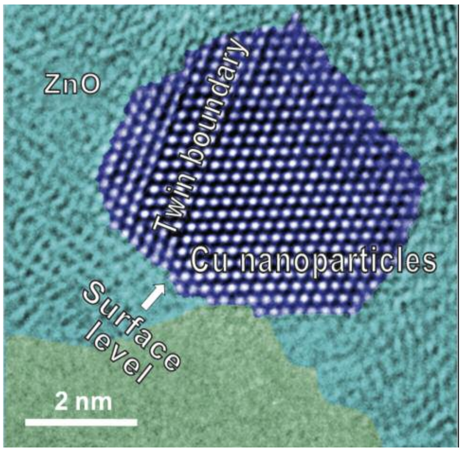
GREATER POWER THROUGH DEFECTS

Scientists at HZB have discovered that **faults in the crystalline structure** of a catalyst increase the reaction speed of methanol synthesis.

Sometimes, industrial applications race ahead of scientific understanding: in the production of methanol, for instance, a certain catalyst comprising copper, zinc and aluminium oxide (Cu/ZnO/Al_2O_3) has proven to deliver the best results. But why this is so has always been a puzzle to scientists. “Given its complex nanostructure, the process had not been especially well understood up to now,” Malte Behrens of the Fritz Haber Institute of the Max Planck Society explains. “With our findings, there is now an answer.” As the head of a project, he led a group of 14 scientists from various establishments, working on the large facilities with teams from the Helmholtz centres.
At a global production of around 50 million tonnes a year, methanol is one of the most important base chemicals, being used in the production of polymers, for instance. Methanol could also play a part in Germany’s energy turnaround, serving as a liquid fuel in future. Industrially used methanol is currently obtained from coal and crude oil. Production takes place using a methanol synthesis catalyst at temperatures from 200–300°C and under pressures of 50–100 bar. For their experiment, Behrens and colleagues compared the results from five different catalyst surfaces with those obtained using a pure copper surface. They reproduced the conditions of industrial catalyst production using nanoparticles 5–15 nm in size and comparable reaction conditions such as pressure, temperature and synthesis gases.

Agreement of theory and experiment

“The neutron experiments showed that the most active catalysts are those with the most building errors in the crystalline structure,” explains Michael Tovar, who is responsible for the neutron powder diffractometer E9 at Helmhotz-Zentrum Berlin. During catalyst synthesis, so-called crystal structure defects arise, which are deviations from the ideal structure in the form of dislocations, grain boundary defects and stacking faults. Where these meet on the surface of the copper particles, the atoms have no direct neighbours, and the result is highly reactive centres with high surface energies.



Electron micrograph of a copper nanoparticle in a highly active Cu/ZnO methanol synthesis catalyst. Lattice structure faults such as the twin boundary pictured here terminate at the particle surface, producing surface defects.

Concurrently to these experiments, scientists from Stanford University delivered calculations based on the density functional theory. “The theoreticians showed that the presence of zinc and the structure of the surface are significant factors,” Behrens explains. “It was very fitting that the observed experimental properties proved to be critical parameters in the theory as well.” The scientists believe these surface defects make the catalyst efficiency significantly higher than the values previously calculated for an entirely free Cu surface.

Long-term studies at the neutron source

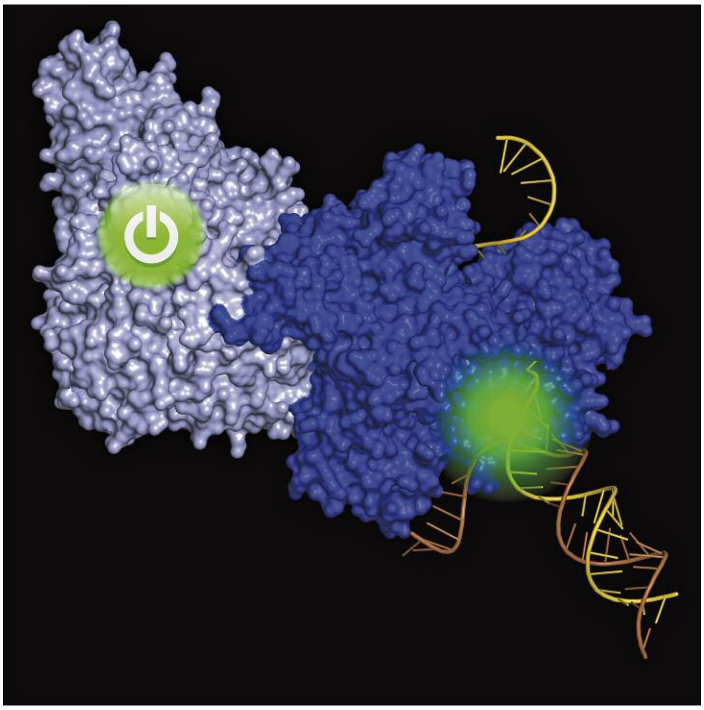
The cooperation went very well and will be continued, Behrens reports: “We have always worked closely with the colleagues from HZB. Currently, we are studying catalyst stability in a long-term project at the neutron source. For this, we are using the neutron diffractometer to answer the questions of how the defect structure changes over time and how the methanol synthesis catalyst reacts in different environments.” *ve*

Science 336, 893 (2012); (DOI: 10.1126/science.1219831): The Active Site of Methanol Synthesis over Cu/ZnO/Al_2O_3 Industrial Catalysts, M. Behrens, F. Studt, I. Kasatkin, S. Kühl, M. Hävecker, F. Abild-Pedersen, S. Zander, F. Girgsdies, P. Kurr, B.-J. Kniep, M. Tovar, R. W. Fischer, J. K. Nørskov, R. Schlögl

FINDING FAULTS IN THE CELL BUILDING SET

Scientists from FU Berlin and MPI worked at BESSY II to study the enzyme Brr2, an important **control unit in living cells**. Understanding how it works could provide a key to healing visual impairments.

To a biochemist like Prof. Dr. Markus Wahl of the Institute for Chemistry and Biochemistry of Freie Universität Berlin, the cells of plants, animals, yeasts and fungi are rather like an anthill: something is always going on inside them, non-stop, but exactly how these processes occur and what they accomplish is often a mystery to the researcher. Only one thing is certain: little at all would happen inside a living cell without these precisely coordinated reactions. If even one of these processes breaks down, the consequences can be fatal. The enzyme Brr2, for instance, plays a vital role in creating copies of the building instructions for producing certain proteins. Errors in this enzyme cause people to lose their eyesight when they are still young. Wahl was accordingly very keen to study this enzyme more closely using the modern tools of structural biochemistry.



The enzyme Brr2 marked in blue is currently working on the gene copies shown in yellow and red at the fluorescent green blotch on the right; on the left is the grey switch unit.

Essentially, every cell stores the building instructions, or blueprints, for all proteins in its DNA. In turn, many structures of the cell consist entirely or in part of these same proteins. Before a protein can be built, the cell first has to make a copy of the blueprint, otherwise known as a "genetic code" or in short a "gene". This copying process is far from straightforward, since the blueprints are frequently interrupted by variously sized segments containing no building instructions at all. Such insertions, called "introns" are first copied along with the building instructions and then subsequently cut out again in a process called "splicing".

Controlling the intron cutter

"Splicing is a highly complex process involving many different proteins and other molecules in the cell," Markus Wahl explains. All together, these components make up a "spliceosome", a molecular machine that ensures the correct excision of the intron. The spliceosome actually exists as a kind of building set. With each new step of the process, new components are added to the molecular machine while other, no longer needed components are discarded. In other words, for each step, the spliceosome picks out the right tools and puts away the tools it no longer requires. Brr2 is an enzyme involved in this tool selection, and controls the unpacking of the cutting mechanism that excises introns. Unlike other parts of the spliceosome, however, the helmsman remains on deck even when no longer needed. That means a signal has to be given to switch Brr2 on and then off again to make sure the intron cutter is unpacked when, and only when, it is needed.
But how does this signalling and controlling work? To find out, Karine Santos and Markus Wahl of FU Berlin together with Sina Mozzafari Jovin and Reinhard Lührmann of the Max Planck Institute for Biophysical Chemistry in Göttingen

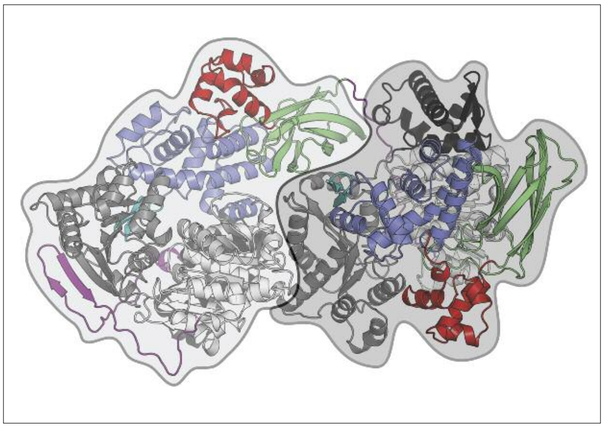
studied Brr2 in greater detail. “In greater detail” means they wanted to see how the very atoms of the protein are arranged. They could not use visible light, as it has much too long a wavelength to resolve individual atoms. What they needed instead was brilliant X-ray light of very short and precisely defined wavelength. Only this can resolve structures of atomic size. Accordingly, Markus Wahl and fellow structural biochemists worked at the synchrotron source BESSY II at HZB, which delivered precisely the X-ray light they needed at the quality they needed.

Two different halves of a protein

To begin with, the researchers grew crystals of the protein, since its atoms can only be studied when arranged in a regular pattern. This only works for some proteins, and luckily Brr2 is one of them. Inside the crystals, X-ray light is deflected by the atoms. Working from the scatter patterns of the X-rays, sophisticated computer programs calculate how the individual atoms are arranged.
Before performing this X-ray crystallography, the researchers already knew that Brr2 comprises two halves that are very similar but which exhibit a number of differences. Indeed, it turned out that only one half of the double protein acts as the control unit for unpacking the intron cutter, while the other half apparently regulates the active half. The regulator for switching Brr2 on and off may accordingly reside in the half of the enzyme that is not responsible for controlling the spliceosome. This part may also regulate the speed at which the intron cutter is unpacked. While the regulating half is not directly involved in this process, the cutting tools are namely unpacked much faster with the help of the regulating unit than without.
Markus Wahl already has a suspicion as to how one half regulates the other: “In the half not responsible for unpacking the intron cutter, we see regions where ATP binds,” the biochemist reports. “ATP” stands for adenosine triphosphate. Living cells often use this small molecule as a kind of battery that stores energy and, when needed, rapidly delivers this energy to the cell. In the regulating unit of Brr2, however, this battery delivers no energy at all. So, for what reason does this half of the enzyme pick up ATP? Perhaps it is the very step that controls the unpacking speed of the intron cutter?

Serious errors in splicing

But why does the speed at which the cutting tools are unpacked have to be varied? In answer to this question, Markus Wahl talks of “alternative splicing”: there are many genes that namely encode the building plans for more than one protein. When reading from one of these genes it may be necessary, for example, to remove all introns in order to build one particular protein, but to leave one or even several introns included to build a different protein. So, if a gene contains several potential introns then, from the same



The active area of the enzyme Brr2 on the left side is very similar to its regulating unit on the right.

genetic blueprints, it can produce many different proteins by alternative splicing. This incidentally explains how a human cell can produce several hundred thousand different proteins out of only around 33,000 genes.
Alternative splicing can accordingly lead to extreme differences. In the fertilized egg cell of the fruit fly Drosophila, for instance, an alternative in one particular gene decides whether the insect will be male or female. If Brr2’s regulating unit controls the speed at which it unpacks the intron cutter, then perhaps it can also control which alternative is preferred during splicing. Maybe it is precisely this subtle control method that plays a role when young people’s eyesight deteriorates because errors have crept into their Brr2? These are speculations that Markus Wahl and his colleagues will be working to resolve in future.

rk

Proc. Natl. Acad. Sci. USA, 2012; 109 (43): 17418-23. (DOI: 10.1073/pnas.1208098109): Structural basis for functional cooperation between tandem helicase cassettes in Brr2-mediated remodeling of the spliceosome, Karine F. Santosa, Sina Mozaffari Jovinb, Gert Webera, Vladimir Penab, Reinhard Lührmann and Markus C. Wahl

IN BRIEF

- The enzyme Brr2 plays an important role in the body for so-called splicing, during which copies of building instructions for producing proteins are made.
- Errors in this process can cause disorders such as visual impairment.
- A research group studied the process at the atomic level using X-rays from BESSY II.
- More research is needed, however, to develop concrete therapeutic methods.


PASSED

HIGHLIGHTS FROM OUR OWN RESEARCH

At the end of 2012, 1,173 employees worked at Helmholtz-Zentrum Berlin für Materialien und Energie, including 66 trainees on a basic or special funding basis. 307 women are employed at HZB, equating to around 26 percent of employees.

Eleven patents were awarded to HZB in 2012, of which eight were in the field of renewable energy and three in the field of photons, neutrons and ions (PNI). HZB's patent portfolio encompassed 349 property rights at the end of 2012, 101 relating to the programme structure of matter and 248 relating to the programme renewable energies.

478 ISI-cited publications were published by scientists at HZB in 2012. On top of these were 42 lectured publications, including the number of books and book contributions mentioned separately in the programmes. In total, 377 publications were from the field of PNI and 143 from the field of renewable energies.

130 PhD students were supervised by Helmholtz-Zentrum Berlin in 2012. 79 of these researched in the field of PNI and 51 in the field of renewable energies for their thesis.

HZB maintained 164 cooperatives with industry in 2012. Of these, 101 were in the field of renewable energies and 63 in research with photons, neutrons and ions.

SANDWICH-STYLE MAGNETIC VALVE

A magnetic valve developed at HZB provides the basis for building better **non-volatile data memories** – and helps answer hitherto unresolved fundamental questions of nanophysics.

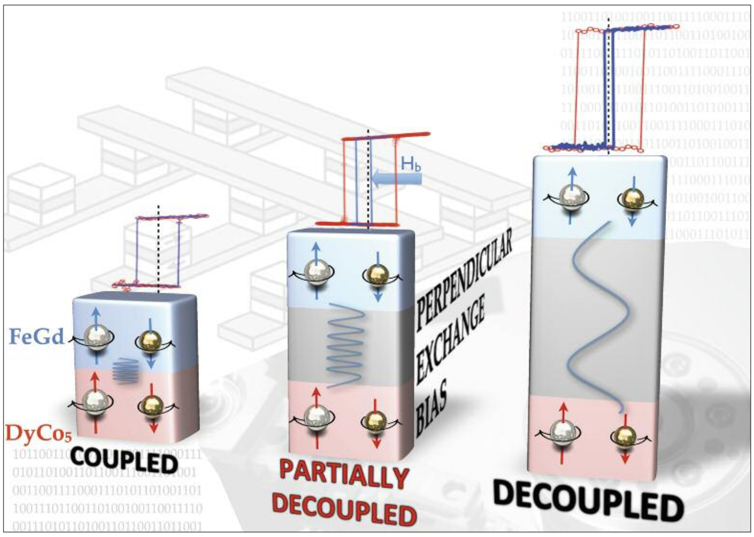
Magnetic memories have a clear advantage in that they retain the digital data stored on them even when the power is turned off. This distinguishes them from conventional electrical memories, which lose their data the instant the continuous current maintaining it is interrupted. Data accordingly has to be loaded into this volatile main memory from another storage medium, such as a hard disk, every time the computer is turned on. This time-consuming booting is not necessary with magnetic memories.

MRAM technology is one example where computer data is stored magnetically these days. Being relatively expensive, however, these components have not really taken off on the market yet. Also, they can only store information for a limited amount of time. Even in MRAM, thermal effects will namely cause the data memory to gradually degrade after a few years. Now, HZB scientist Dr. Florin Radu has found an elegant solution to overcome this limitation.

Studying magnetisable layers

Driven purely by scientific curiosity at first, Radu and research colleagues began studying the behaviour of densely packed, ultra-thin magnetisable layers at his laboratory at HZB. The physicist, who conducted his research at the Berlin Institute for Complex Magnetic Materials, prepared two layers of different magnetisable metal alloys for studying under an external magnetic field. His aim was to modify the macroscopic magnetic properties of the material combination and find out what happens at the atomic scale as he did so.

The researchers worked with two metal alloys: one of iron and gadolinium and the other of cobalt and dysprosium. The common feature of these substances is that they are both ferrimagnetic. This is a term physicists use to describe solids whose spins – characteristic quantum mechanical properties of the atoms – are in antiparallel alignment, i.e. parallel to each other but pointing in opposite directions. It follows that their atomic magnetic moments, which are inextricably associated with their spins, are also antiparallel. Despite the opposing orientation of the spins, however, a weak, externally acting magnetic field still exists overall because the atomic magnets of one element in the alloy are stronger than those of the other element and therefore do not fully cancel out. The two material layers used in the study differ in that the iron-gadolinium alloy is magnetically "soft", meaning its properties can be relatively easily manipulated by an external magnetic field, whereas the cobalt-dysprosium alloy is magnetically "hard" – and is therefore relatively insusceptible to external fields.



The hard and soft ferrimagnetic alloys (blue and red) without a separating layer are closely magnetically coupled and mutually influence each other. A separating shim of tantalum (grey) allows their magnetic alignments to be separately controlled by an external magnetic field. This makes the layers useful as magnetic data memory.

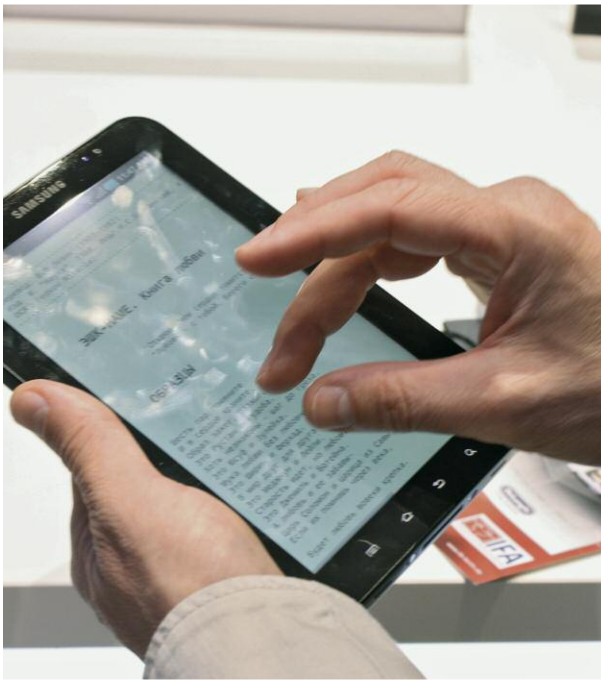
Strong forces at the interface

The experiments on the pair of thin films proved more difficult than Florin Radu's team had expected. The forces at the interface between the two material films were so strong

that the layers became powerfully magnetically interlocked and were almost impossible to separate by external influences. The HZB scientists, collaborating on this experiment with fellow researchers from Ruhr-Universität Bochum and the Dutch University of Nijmegen, therefore devised a trick: they inserted an insulating layer of tantalum only a few atom layers thick between the ferrimagnetic films. This thin shim dampened the magnetic forces, allowing them to partially decouple the two other layers. “Even so, we were still able to characterise the magnetic interaction through the intermediate layer,” Radu reports – which weakened as they increased the thickness of the layer. In the end, this arrangement turned out to be highly practical: the researchers were able to control the state of the magnetically softer metal in a targeted and precise manner by gently varying an external field. The magnetically hard counterpart in the material sandwich remained largely unaffected by this – and thereby served as a fixed magnetic “anchor” for the overall system.
The surprising experimental results raise new hopes in digital memory technology. The layer system studied behaves like a “magnetic valve” or “spin valve” – an entity with highly promising characteristics for data storage. It could be used to create memory modules that conserve information using magnetic effects and not electrical voltages, as do the main memories used so far in most computers. The magnetic valve created by Florin Radu and fellow researchers from Bochum and the Netherlands even offers clear advantages over existing magnetic memories based on MRAM technology.

Controlling how long data will be stored

“In our system, you can control the volatility,” Radu says. “That is truly novel.” One can arbitrarily define whether the stored information shall be conserved for weeks, months or many years. After that, the system can be restored to its original state and refilled with new data. “The life span of such a memory is essentially unlimited,” says Radu. “So I would not be surprised if spin valves were to find their way as data memories into personal computers, smartphones or tablet computers.”
HZB already submitted a patent application for the discovery to the German Patent Office in the spring of 2012. An application for an international patent should follow soon. In the meantime, the researchers at HZB are busy working on improving the practicality of their clever system even further. “We intend to use a laser in future to influence and control the magnetic states,” reveals Radu, who is also collaborating with companies from the computer industry. Yet, the physicist sees the greatest value of his discovery in the new fundamental knowledge they have gleaned from it. The physical processes in the exotic sandwich allow a deep insight into the interactions between nanometre-thin layers. And that offers the chance to understand an effect



According to HZB scientist Dr. Florin Radu, spin valves could find their way as data memories into tablet computers and smartphones.

that was discovered more than 50 years ago, namely exchange anisotropy. This phenomenon, which occurs between ferromagnetic and antiferromagnetic films, is used in the read/write heads of most modern hard disks. “Yet the details of the physical processes hiding behind this effect are still not fully understood to this day,” says Florin Radu. “There are a number of theories about it – but it is still unclear which description is correct.” Radu is convinced that the insights into the magnetism of thin layers gained at HZB will finally clarify the issue.

rb

Nature Communications, 3, 715, (DOI: 10.1038/ncomms1728): Perpendicular exchange bias in ferrimagnetic spin valves, F. Radu, R. Abrudan, I. Radu, D. Schmitz and H. Zabel

IN BRIEF

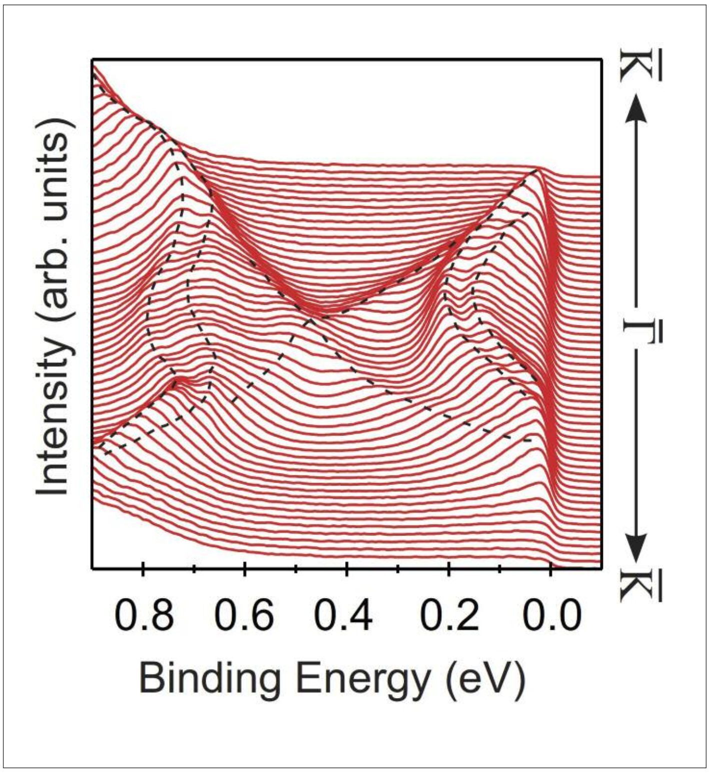
- In magnetic memories, data can be stored even without a continuous supply of current. So far, however, they are too expensive and unreliable.
- HZB researchers have discovered a so-called magnetic valve in experiments on ultra-thin magnetisable layers.
- They could theoretically be used to build memory that can store data indefinitely using magnetic effects.

A CLOSE LOOK AT TOPOLOGICAL INSULATORS

HZB scientists have studied in depth a new class of materials called topological insulators. Quantum effects give them unusual properties at room temperature. They could be an option for **quantum computers** and ultrafast switches.

A few years ago, quantum mechanics theoreticians astounded the scientific community with the following prediction: there must be a crystal whose surface makes an extremely good electrical conductor, but whose bulk inside is an insulator. They dubbed this crystal a topological insulator, and of course stated reasons as to why it must exist: it has to do with the states the electrons on the surface and inside the crystal can assume. The electrons' spin and direction of motion are strongly coupled.

Shortly afterwards, the first topological insulators were in fact discovered, including the three familiar binary chalcogenides Bi_2Se_3, Bi_2Te_3 and Sb_2Te_3. They owe their special properties to their band structure because, directly on the surface, the so-called band gap between the conduction and valence band disappears. Inside the bulk of these binary chalcogenides, on the other hand, is a large band gap that the bound electrons cannot overcome. Band gap refers to the distance between the two energy bands in which the electrons can reside. Bound electrons reside in the so-called valence band, while mobile electrons responsible for the flow of current through a material reside in the conduction band. If there is no band gap then, when energy is input in the form of light or a voltage, the charge carriers in the valence band also become highly mobile and



Spectra of a one-third atomic layer of iron on bismuth selenide. Intersecting lines indicate the surface state. The upper and lower parts of the picture are symmetrical due to time reversal symmetry, which also protects the point of intersection.

GERMAN-RUSSIAN RESEARCH GROUP ON TOPOLOGICAL INSULATORS

In December 2012, the Helmholtz Association and the Russian Foundation for Basic Research founded a new "Helmholtz-Russia Joint Research Group". The objective of this joint research group is to study the new material class of topological insulators, which promise interesting applications in computer technology. They expect intensive exchange here, from which upcoming scientists in particular shall benefit. The new research group, among which HZB physicist Dr. Andrei Varykhalov and chemist Prof. Dr. Lada V. Yashina of Moscow State University will be working together, commenced work in January 2013. The funding amounts to 150,000 euros per year over maximum three years.

can therefore jump over to the conduction band and contribute to the current.

Large band gap at room temperature

Since then, topological insulators have been discovered in many ordinary materials and even at room temperature. That means the band gap is very large indeed, since electrons at room temperature have enough energy from their thermal agitation alone to overcome small band gaps. The most well-known material of this kind is bismuth selenide. A group led by Prof. Dr. Oliver Rader of HZB's Department of Magnetisation Dynamics is currently studying this material, while Markus Scholz coated bismuth selenide with iron and then measured the surface state of the samples for his doctoral thesis. Interfaces between a topological insulator and ferromagnetic material such as iron would be highly interesting for developing new memory media in the computer industry.

Scientists have so far assumed that coating with a strongly magnetic material would disrupt the surface state that makes topological insulators what they are. The stability of a topological insulator's surface state is namely due to the fundamental physical principle of time reversal symmetry. This principle dictates that physical laws apply equally even if time runs backwards. When it comes to the motion of electrons in a solid, this means the natural laws apply regardless of whether the electron moves from left to right or – when time is reversed – from right to left. The rule here is that when an electron moves in a specific direction, say to the left, it must be able to assume an up spin state. By the same token, an electron moving in the opposite direction must be able to assume a down spin state. In topological insulators, this coupling of the direction of motion and spin is so strong that the electrons on the surface are constantly forced to remain available to conduct electric current. In other words, the conductive surface states are protected.

Topological insulators on the testbed

Things are different in ferromagnetic materials. In these, the direction of spin is determined by the magnetic north and south pole. Time reversal symmetry breaks down here. If both materials – ferromagnets and topological insulators – are brought into contact, then the ferromagnet's break in symmetry is expected to carry over to the topological insulator. According to the assumptions so far, its surface also ought to become insulating. That would mean new memory materials with topological insulators could not be developed at all.

"When topological insulators were discovered, there was great euphoria at first," Markus Scholz says. "This class of materials was the great white hope in computer technology. Then, the assumption caught on that a topologically protected state – such as the surface state of bismuth selenide – would react extremely sensitively to magnetic materials, and that was a great disappointment." After all, for applications in computer components such as new storage media, it is crucial for the surface state to remain stable even in the immediate vicinity of a magnetic material.

Further research efforts required

In order to find out experimentally how it actually behaves, Markus Scholz first prepared fresh, clean break edges of a bismuth selenide crystal – using sticky tape as Scholz explains: "Structurally, bismuth selenide is essentially two-dimensional. Which means, after five very tightly bonded atomic layers comes a weak bond. The crystal tears off at that point when the sticky tape is pulled off." The group then gave this fresh break edge an extremely thin coat of iron. Next, the scientists studied the coated crystal surface using a highly surface-sensitive measuring technique called angle-resolved photoemission spectroscopy (ARPES). "While this only lets us look one or two atom layers deep into the sample, we can see extremely precisely what is going on," says Dr. Jaime Sánchez-Barriga, co-author of the study.

The result was very surprising and throws into question the careful reasoning as to how topological insulators will interact with ferromagnetic interface layers. Bismuth selenide namely exhibits its topological surface states even after being coated with iron. "That means new research efforts are warranted for continuing to develop bismuth selenide for application in computer research," Sánchez-Barriga argues. "They could be used in making magnetic transistors, for example." The HZB researchers are indeed continuing this research, and the German Research Foundation has even set up a priority program on topological insulators, which Oliver Rader coordinates.

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Phys. Rev. Lett. 108, 256810 (2012), (DOI: 10.1103/PhysRevLett.108.256810): Tolerance of Topological Surface States towards Magnetic Moments: Fe on Bi_2Se_3, M. R. Scholz, J. Sánchez-Barriga, D. Marchenko, A. Varykhalov, A. Volykhov, L. V. Yashina and O. Rader

IN BRIEF

- Topological insulators conduct electricity extremely well on their surface, but not at all inside their bulk.
- Combined with a ferromagnetic material such as iron, they could be used to build a new type of data storage.
- HZB researchers experimentally coated the topological insulator bismuth selenide with iron and studied the boundary layer in depth.
- Contrary to expectation, they discovered that the materials do not negatively interfere with each other.

MAKING COMPONENTS OUT OF GRAPHENE

Physicists working with Dr. Andrei Varykhalov and Prof. Dr. Oliver Rader have studied graphene at BESSY II. They have successfully explained two phenomena and reached the first objectives on the path towards building components out of graphene. These could form the basis for novel electronics or even **spintronics**.

Hardly any other element exists in such a diversity of forms as carbon: from sparkling and extremely hard diamond to mundane coal, from soft graphite to the current sensation of nanoparticles in the form of soccer balls made from 60 or 70 carbon atoms and carbon nanotubes. It also exists in a two-dimensional form named graphene. Were it possible to produce free-floating graphene, it would have astonishing properties. A single layer of it could support the weight of a cat.

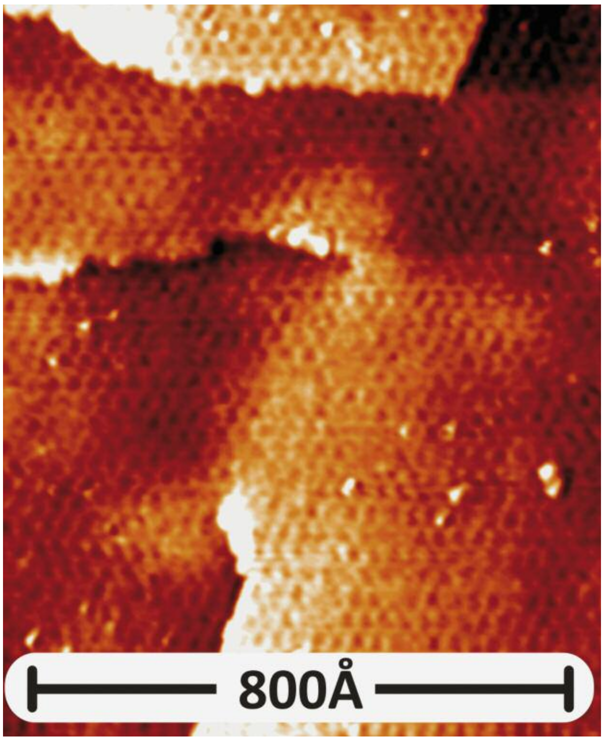
Perfect graphene consists of a single layer of carbon atoms forming a hexagonal net. The tetravalent carbon atoms alternately form double and single bonds and yield amazing properties: perfect graphene would be extremely conductive, transparent and strong. Researchers believe it could replace many of the semiconductor materials used today. Its special net arrangement is responsible for the enormous mobility of the charge carriers in graphene. Unfortunately, quantum mechanical calculations reveal that this network is thermodynamically unstable. Nevertheless, in 2004, André Geim and Konstantin Novoselov succeeded in actually detecting graphene, for which they received the 2010 Nobel Prize for Physics.

Graphene – no ordinary semiconductor

What physicists find most interesting about graphene are its electronic properties, which differ significantly from those of an ordinary semiconductor. Quantum physics shows that in semiconductors, electrons can assume only certain energy values. This gives rise to two energy bands in which the electrons can reside: the valence band for bound electrons and the conduction band for mobile electrons. Between these is a so-called band gap which an electron from the valence band would need to cross, boosted either by an external voltage or by light, in order to contribute towards the flow of current in the conduction band. This band structure is the basis of all present-day semiconductor components.

In two-dimensional graphene, however, the band structure is radically different. The conduction band and valence band are shaped like two cones touching at the apexes – known as Dirac cones. That means, unlike in ordinary semiconductors, in graphene the electrons from the valence band can move practically freely throughout the crystal lattice without any prior energy boost. Even the optical properties are different from those of conventional semiconductors. Graphene allows a broad spectrum of light to pass through almost entirely unhindered, making it totally transparent.

Yet, in reality, there is no perfect graphene. While tiny flakelets of it can be created by sticking a small amount of



A scanning tunnelling micrograph shows the topography of graphene on gold. Superimposing the gold structure over the hexagonal honeycomb structure of graphene creates a regular superstructure (Moiré structure) that is ten times larger than the mesh of the graphene net. This influences the chemical interaction between the two atomic layers and thus also the electronic properties and spin behaviour.

graphite, say from a lead pencil, between two pieces of sticky tape and stripping them apart, larger graphene layers typically have to be vapour-deposited onto a metallic substrate layer in a vacuum. The atoms of the metallic substrate then exert forces on the carbon atoms lying on them, meaning the supposedly flat honeycomb network becomes an undulated landscape of hills and valleys.

Electrons behave like light

The HZB physicists studied graphene deposited onto a layer of nickel. They chose nickel because it has a similar lattice constant to graphene, meaning there should only be minor deformation. They studied their samples by photoelectron spectroscopy at BESSY II in order to determine the electronic structure. To interpret the results of their measurements, they worked with theoretical physicists from universities in Würzburg and Bremen and from the Trieste Institute for the Structure of Matter in northern Italy.

They were able to detect the "Dirac cones" and to show that the conduction electrons even behaved more like light and less like particles on this substrate. Physicists had in fact expected this behaviour, but only on free-floating graphene layers with a perfect honeycomb structure, and not in graphene resting on nickel, which distorts the perfectly hexagonal symmetry. "These results are surprising," says Dr. Andrei Varykhalov of the Department of Magnetisation Dynamics at HZB. The reason is that the nickel atoms interact in two different and mutually compensating ways with the carbon atoms of the graphene. On the one hand, they destroy the perfect hexagonal symmetry of the graphene lattice. On the other hand, they provide the graphene layer with extra electrons – which compensates for the damage caused by the lattice distortion. "We have uncovered a fundamental mechanism that is interesting for possible applications," Varykhalov asserts. Because graphene is always applied to a substrate as a rule, the extra "healing" electrons could well be fed in using an external electrical voltage, for example.

Gold atoms reinforce the spin-orbit coupling

In another study, together with physicists from Forschungszentrum Jülich, from Harvard University and from the State University of St. Petersburg, the HZB experts took another close look at graphene on nickel. This time, however, they vapour-deposited the samples together with gold atoms which crept between the graphene and nickel. Using spin-resolved photoemission spectroscopy at BESSY II, they observed how the presence of gold atoms affected the so-called spin-orbit coupling of electrons in the graphene. Just like the earth, electrons have two angular momenta: their orbital angular momentum, which takes them around the atomic nucleus, and their spin, which is akin to an intrinsic rotation. These two angular momenta mutually influence each other, so we speak of spin-orbit coupling. The stronger this coupling, the greater the energy difference between the state in which spin and orbital angular momentum are aligned to one another and the state in which they are oppositely aligned. In light nuclei such as in carbon atoms, the interaction between spin and orbit is rather weak, but in heavy atoms such as gold atoms, this interaction is very strong.

Strong spin-orbit coupling

The effect in the experiment was huge and much stronger than expected: "We showed that the gold atoms increase this interaction in the graphene layer by a factor of 10,000 due to their proximity to the graphene layer," reports Dmitry Marchenko, who performed the measurements as part of his doctoral studies. This very strong spin-orbit coupling would make it possible to build a kind of switch, Varykhalov explains, since an electric field could flip the spins of the electrons. Two spin filters before and after the component would each allow spins through in only one direction. If the spin filters are placed perpendicularly to each other, then no electrons would get through and the switch would be closed. An electric field, however, would flip the spins such that the switch could be turned either partially or completely open. Nevertheless, a real switch would ultimately require a non-conductive base, meaning the metallic nickel substrate would have to be replaced. The HZB researchers are already experimenting on silicon carbide as an ideal substrate for this.

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Nature Communications 3, (DOI: 10.1038/ncomms2227): Giant Rashba splitting in graphene due to hybridization with gold, D. Marchenko, A. Varykhalov, M.R. Scholz, G. Bihlmayer, E.I. Rashba, A. Rybkin, A.M. Shikin & O. Rader

Phys. Rev. X 2, 041017 (2012), (DOI: 10.1103/PhysRevX.2.041017): Intact Dirac Cones at Broken Sublattice Symmetry: Photoemission Study of Graphene on Ni and Co, A. Varykhalov, D. Marchenko, J. Sánchez-Barriga, M. R. Scholz, B. Verberck, B. Trauzettel, T. O. Wehling, C. Carbone and O. Rader

IN BRIEF

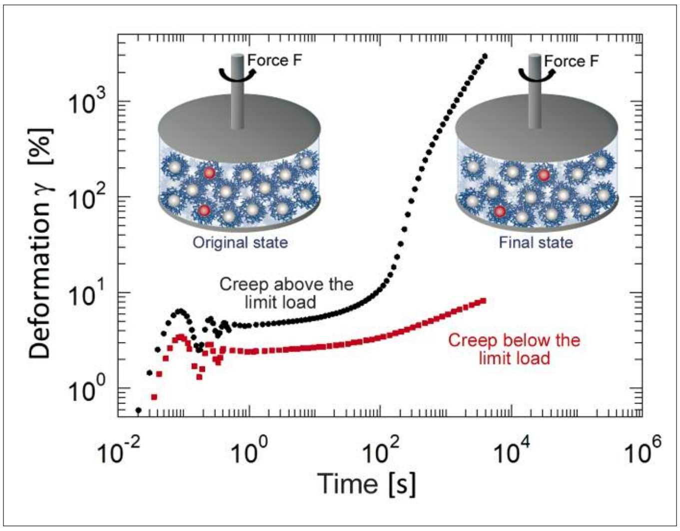
- Graphene consists of carbon and is hailed as a material of the future for building semiconductors.
- HZB physicists studied graphene on a layer of nickel and detected an ideal typical behaviour of graphene.
- The behaviour of graphene electrons was studied in greater depth in further experiments. An electrical effect was discovered that could be put to practical use.

WATCHING MATERIALS CREEP

Scientists at HZB studied **creep processes in solids** in an experimental model system and have described their behaviour with a new theoretical model. Their results provide a better understanding of materials and, with it, help prevent technical disasters such as bridge collapse.

Tragic misfortune in paradise: on 26 September 1996 in the Pacific republic of Palau, the 240-metre-long arch of a pre-stressed concrete bridge collapsed following renovation and repair measures. Two men died and four were injured. Experts had declared the bridge safe only shortly before its reopening. But they had not considered so-called creep processes in the concrete. Under constant load, the material deforms even if the forces acting on it are far below the actual limit load.

Prof. Dr. Matthias Ballauff and Dr. Miriam Siebenbürger of the Institute of Soft Matter and Functional Materials at HZB have made a detailed study into these non-linear creep processes in solid substances. They employed an experimental model system comprising tiny particles (colloids) in an aqueous solution. The model particles used were spherical core-shell colloids. The 70-nanometre-diameter core is made of the plastic polystyrene, which is insoluble in water, and the approximately 50-nanometre-thick shell is made of networked poly(N-isopropylacrylamide). The advantage of these coated colloids is their thermosensitivity. Because their size can be varied greatly with temperature, the researchers can study the same particles at different packing densities. When studying the problem of creep, they used such a high packing density that the material actually became an unordered solid – a so-called glass. In a rheometer, an instrument for measuring the deformation and flow behaviour of matter, Miriam Siebenbürger studied how this glass behaves under different loads. The results of the measurements revealed complex deformation behaviour with five different laws applying dependent on the time and strength of the load.



Creep processes in materials depend greatly on external conditions. HZB scientists observed in a rheometer how particles (red) in a solid material (blue) move independently of time and load.

Experiment consistent with theory

The experimental results were compared with a new theoretical model developed by physicist Dr. Thomas Voigtmann (of the University of Konstanz and the German Aerospace Centre, DLR, in Cologne). The model of this so-called mode-coupling theory calculates the behaviour of hard spheres at high packing density for various loads. Despite the complex temporal behaviour, the theory can describe the experimental data very well. Given the universality of the theory, material fatigue due to creep can be generally predicted and even applied to other materials such as metals. The researchers hope that their approach will be applied when developing new materials in vehicle and aircraft construction, for instance. Creep processes namely occur at relatively low temperatures in many light metal alloys.

Using neutrons from the Berlin neutron source BER II, Miriam Siebenbürger intends to gain an even better understanding of her samples. “You can’t look directly into the material using a rheometer. We want to change that now,“ the researcher declares. And indeed they shall, by building the rheometer onto beamline V16 so as to research the structural changes deep inside the deforming material.

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Phys. Rev. Lett. 108, 255701 (2012), (DOI: 10.1103/PhysRevLett.108.255701): Creep in Colloidal Glasses, M. Siebenbürger, M. Ballauff and T. Voigtmann

TELL-TALE ASYMMETRY

Some magnetic materials can assume a collective state in which their atomic building blocks are strongly correlated. HZB researchers have studied this **exotic phenomenon** in greater detail.

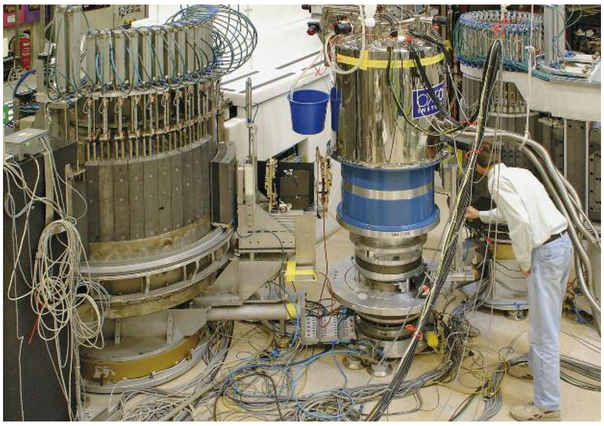
At low temperatures, some substances exhibit strange properties that do not tally with everyday experience. Examples of this are superconductivity, where electrical resistance disappears, and superfluidity, which allows liquids to creep up walls. Unusual things also happen in magnetic materials. Certain materials possessing a rare structure – called Haldane chains, spin ladders or one-dimensional dimer chains – enter a state when cooled that binds the elemental atomic magnets together as if by an invisible chain. Physicists call this a coherent mode and can detect it experimentally by bombarding the material with neutrons. The neutrons excite the collective of particles, the so-called magnons, and produce a characteristic excitement spectrum. As the temperature rises, these excitements change: they broaden. Their shape, which remains symmetrical in "ordinary" materials, becomes asymmetrical in exotic materials.

"This linewidth broadening is a consequence of impacts between the magnetic excitements due to their thermal motion," explains Dr. Diana Quintero-Castro, researcher at Helmholtz-Zentrum Berlin. The physical term for this is thermal decoherence. Impacts shorten the "lifetime" of the excited magnetic states, which manifests itself as a "blurring" of the spectral line. "The asymmetry, on the other hand, comes about by collective magnetic excitement, which acts as a repulsive force and braces itself against the impacts."

Dimer system under neutron fire

A group of researchers from HZB and the Institute of Solid State Physics of TU Berlin led by Prof. Dr. Bella Lake, together with colleagues from France and Switzerland, have now detected this effect for the first time in an ordinary magnetic material. The scientists used the high-resolution three-axis spectrometer FLEXX – a neutron scattering facility at HZB – and a similar set-up at the Paul Scherrer Institute in Villingen, Switzerland. They fired neutrons at a dimer system with antiferromagnetic properties. Dimers are constructs of two subunits that are largely identical, but which can be in different magnetic states depending on their orientation to each other. The states differ in terms of energy content and magnetic behaviour. The dimer system studied in this work consisted of strontium, chromium and oxygen and has the chemical formula $Sr_3Cr_2O_3$.

In this material, there are many energy states distributed over a broad spectrum. The physicists had not expected to encounter collective magnetic excitements in such a substance. Yet the results of the neutron scattering experiments refute this conventional picture. In order to analyse the temperature dependency of the magnetic excitements, Bella Lake and fellow researchers bombarded crystalline samples of the chrome-containing compound with neutrons of various energies, and measured the magnetic excitement spectrum at temperatures between 1.6 and 40 kelvins. It turned out that, as expected, the lines became weaker and wider as temperature increased. Yet they also took on an increasingly asymmetrical shape as they did so. "This proves that a strong magnetic force is acting in this material that couples the magnetically excited states coherently together," says Diana Quintero-Castro. This surprising experimental finding in what the physicists had considered a relatively mundane magnetic material suggests that this phenomenon occurs in far more materials than one would expect from the existing conventional models. Strange properties appear to be extremely common in the microcosmos. *rb*



With the three-axis spectrometer FLEXX, scientists at HZB were able to analyse the magnetic behaviour of a chromium compound in depth.

Phys. Rev. Lett. 109, 127206 (2012), (DOI: 10.1103/PhysRevLett. 109. 127206): Asymmetric Thermal Line Shape Broadening in a Gapped 3D Antiferromagnet: Evidence for Strong Correlations at Finite Temperature, D. L. Quintero-Castro, B. Lake, A. T. M. N. Islam, E. M. Wheeler, C. Balz, M. Månsson, K. C. Rule, S. Gvasaliya & A. Zheludev

X-RAY VIEW OF LATTICE DYNAMICS

Researchers at HZB used intense laser pulses to vibrate the atoms of a crystalline material. Analysis of this motion has revealed details about **structures and interactions inside solids** that can be exploited in many ways.

Analysing vibrations in a crystal lattice can reveal a lot about the structures and interactions inside a solid. There is a very useful quantum mechanical model that describes all atomic motion in the crystal as a superimposition of different fundamental vibrations: so-called phonons that behave like waves of certain frequencies and amplitudes. Most useful for fundamental physics experiments and for developing technologies – such as tiny sensors that work by measuring vibrations – are phonons of a high, uniform frequency. These can be produced in a targeted manner by excitation using a short succession of laser pulses, as demonstrated by a group of scientists working with Prof. Dr. Matias Bargheer, head of the research group Ultrafast Dynamics at Helmholtz-Zentrum Berlin and professor at the Institute of Physics and Astronomy of Potsdam University. As they did so, they observed the vibrations of the atoms directly under X-ray light at high spatial and temporal resolution.
Bargheer and his group experimented at HZB on a transparent crystal of strontium, titanium and oxygen ($SrTiO_3$) covered with a metallic film made of a strontium-ruthenium compound ($SrRuO_3$). These materials are regarded as suitable candidates for future micro- and nanoelectronics. The physicists fired many extremely short, intense laser pulses at the thin metallic layer. “The thin film served to convert the energy of the laser pulses into intense, high-frequency phonons,” Bargheer explains. These vibrational wave packets were transmitted to the underlying crystal, causing it to vibrate at high frequency.

Crystal lattice under double fire

In order to sound out the dynamic processes on a microscopic scale, the scientists fired X-ray light from the synchrotron source ESRF in Grenoble at the sample. These X-rays also bombarded the crystal in the form of ultrashort pulses. “As it penetrates through the vibrating crystal lattice, some of the X-ray light is diffracted at the phonons and thereby changes its direction and frequency,” Matias Bargheer explains. A spectral analysis of the diffracted X-rays allows the properties of the phonons to be precisely measured. Phonons of a certain frequency create a characteristic line pattern in the X-ray spectrum.
The result of this X-ray diffraction: the laser pulses caused vibrations of almost uniform frequency in the solid which travelled through the crystal in harmony. Friction effects caused these vibrations to gradually decay – with a “lifetime” of around 130 picoseconds (trillionths of a second), as determined from the measured data. “Such values reveal a lot about the processes and forces inside the studied solid,” says Bargheer – especially because different phonons can be generated by varying the frequency of the exciting laser pulses. “It becomes especially interesting

Scientists of the HZB are also using the European Synchrotron Radiation Facility (ESRF) in Grenoble for their experiments.

when you get close to phase transitions, which materials such as strontium titanate exhibit at specific temperatures," the researcher declares. "The attenuation of the vibrations suddenly increases by more than ten times at minus 168 degrees Celsius, even though nothing about the material changes as seen from outside." Bargheer stresses: "It is the tiniest shifts of oxygen atoms in the crystal lattice that call the tune here."
Working with a physical model, the researchers calculated the expected properties of phonons in strontium titanate – and obtained values that tallied well with the experimental data. This means ultrafast X-ray diffraction measurements are an excellent method for discovering the details of the behaviour of a vibrating crystal lattice – not only for the material studied in this case but for many other crystalline materials as well. And X-ray light of even shorter wavelength could deliver even more detailed insights into the complex dynamics of solids such as materials used in solar cells, superconductors or modern, energy-efficient nanoelectronics. *rb*

AAppl. Phys Lett. 100, 094101 (2012), (http://dx.doi.org/10.1063/1.3688492): Detecting optically synthesized quasi-monochromatic sub-terahertz phonon wavepackets by ultrafast x-ray diffraction, M. Herzog, A. Bojahr, J. Goldshteyn, W. Leitenberger, I. Vrejoiu, D. Khakhulin, M. Wulff, R. Shayduk, P. Gaal & M. Bargheer

IN A LABYRINTH OF MAGNETIC DOMAINS

During study of a **ferromagnetic material**, an international research group led by Prof. Eisebitt discovered an effect that could allow smaller and faster data storage media.

The constant, rapid availability of information is one of the most visible and significant changes in our modern living environment. Driven to make laptops, mobile phones and other electronic equipment ever smaller and more powerful, researchers worldwide are on the lookout for suitable materials for increasingly miniaturised and faster data storage media. This is the case for Prof. Dr. Stefan Eisebitt of the Helmholtz-Zentrum Berlin and TU Berlin, who has long been researching magnetic nanostructures and has contributed much to the improvement of study methods in this field. One of the most important things is being able to control a material's magnetisation at high speed. Eisebitt and his colleagues have studied this process on samples comprising a cobalt-platinum layer system.

Changing magnetisation by light pulses

"It has long been known that the magnetisation of a material can be changed locally by light pulses, but now we have observed the process much more precisely and have even discovered a new mechanism," Eisebitt explains. Most ferromagnetic materials namely consist of numerous individual domains of differing magnetic alignment. "When laser light is shone upon them, electrons released whizz through the material and travel from one domain into an oppositely magnetised domain. These electrons thereby carry part of the magnetisation through the sample, and can therefore disrupt the local magnetisation," junior scientist Bastian Pfau of TU Berlin elaborates.
The researchers from TU Berlin, HZB and DESY, together with colleagues from the universities of Hamburg and Paris and six other research institutes including the Stanford Linear Accelerator Center SLAC, USA, conducted their experiments at DESY's free-electron laser FLASH in Hamburg. They had previously characterised the domain pattern at the synchrotron facilities BESSY II at HZB and SOLEIL in Paris. They studied samples of a cobalt-platinum layer system whose nanometre-fine magnetic domains arrange into labyrinthine structures. "Our results also show that the position and density of magnetic domain boundaries can influence the demagnetisation behaviour," Stefan Eisebitt adds. "This delivers a new approach for developing faster and smaller magnetic data storage media, namely by the targeted creation of magnetic nanostructures." *arö*

Nature Communications 3:1100 (2012); (DOI 10.1038/ncomms2108): Ultrafast optical demagnetization manipulates nanoscale spin structure in domain walls, B. Pfau, S. Schaffert, L. Müller, C. Gutt, A. Al-Shemmary, F. Büttner, R. Delaunay, S. Düsterer, S. Flewett, R. Frömter, J. Geilhufe, E. Guehrs, C. M. Günther, R. Hawaldar, M. Hille, N. Jaouen, A. Kobs, K. Li, J. Mohanty, H. Redlin et al.

TAILORED ORGANIC SEMICONDUCTORS

The electronic properties of organic semiconductors can be modified in a targeted manner by **so-called doping**. Berlin researchers have now experimentally shown exactly what happens during doping.

Ultrathin, rollable display screens, room lights that stick on the wall like wallpaper, thin-film solar cells that convert sunlight to energy on cars or house facades – these are just a few visions that can be realised using organic electronics. This promising future technology is based on electrically conductive plastics that can be used to build similar products to those built out of the hitherto dominating electronic substrate silicon – but with easier and cheaper production processes and in flexible form.

In order to adapt their material properties to various applications, organic substances – such as silicon and other inorganic semiconductors – have to be specially prepared: the plastic has to be "doped". "This is done by introducing molecules of a foreign chemical substance into the plastic in a targeted manner in order to lend it new or improved electrical properties – such as greater conductivity through free-moving electrons," explains Dr. Ingo Salzmann, who is researching in the workgroup of Prof. Dr. Norbert Koch at the Department of Physics of Humboldt-Universität zu Berlin. Yet, while the physics of electronic doping is well understood for conventional semiconductors, the fundamental mechanism in plastic electronics is still giving researchers a headache.

Complex processes during doping

"You need unexpectedly large amounts of the foreign substance in order to effect a change in conductivity," Salzmann says. This is expensive and leads to undesirable disturbances in the material. The crux lies in the atomic interior of the material: while doping changes silicon material properties by directly releasing individual electrons, complex processes appear to be at work in organic substances. Salzmann and fellow Humboldt researcher Dr. Georg Heimel have now tracked down these processes in experiments performed at the laboratory at HZB. The two researchers were supported by Dr. Alexander Schnegg of the HZB Institute for Silicon Photovoltaics.

The Berlin scientists used various measuring techniques to study different plastics. "All substances studied belong to a relatively compact class of organic materials," Salzmann explains: their molecules consist of 20 to 50 carbon atoms as well as atomic components of various other chemical elements. The researchers doped these substances with foreign molecules. They then performed photoelectron spectroscopy, X-ray scattering and electron spin resonance measurements to analyse what went on inside the material.

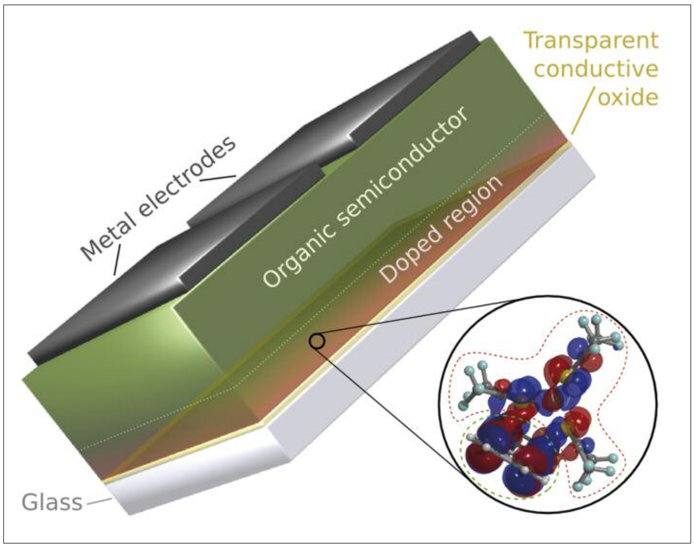


Diagram of an organic electronic component with doping molecules (brown inclusions) in the active film (green). Pictured on the right is the enlargement of a molecular load transfer complex and a hybrid orbital.

Creation of an intermolecular complex

"This way, we were able to discover what quantum mechanical energy levels formed in the doped material and how many free-moving electrons existed," Salzmann reports. The researchers used this knowledge to reconstruct the molecular processes taking place during doping. The surprising result: unlike in silicon, for example, electrons do not simply migrate from the doping molecule to the doped plastic. "Instead, an intermolecular complex is created," the researcher explains. This is a kind of loose compound of a plastic and a foreign molecule. "These complexes first have to be excited by adding enough energy for moving charge carriers to appear, which then increase the conductivity of the organic material." Simulations confirm the experimental findings.

Creating new functionalities

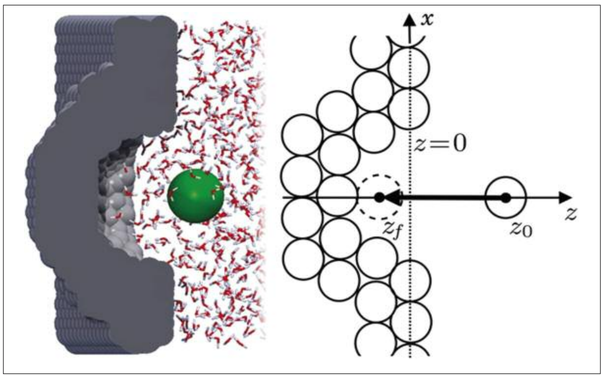
The Berlin physicists hope that knowledge of these molecular processes will help choose targeted doping substances that produce the desired molecular properties most efficiently every time. The ball is now in the court of their chemistry colleagues to synthesise suitable compounds. "With these, we will be able to produce organic electronic products more cheaply and with better properties," Ingo Salzmann is convinced. "And entirely new functionalities that have never been achieved before will probably become possible." *rb*

Phys. Rev. Lett. 108, 035502 (2012), (DOI: 10.1103/PhyRevLett. 108. 035502): Intermolecular Hybridization governs Molecular Electrical Doping, I. Salzmann, G. Heimel, S. Duhm, M. Oehzelt, P. Pingel, B.M. George, A. Schnegg, K. Lips, R.-P. Blum, A. Vollmer & N. Koch

WATER AS A DOOR OPENER

HZB researchers led by Prof. Dzubiella have experimentally proven that water is more than just a solvent when transporting **active pharmaceutical ingredients**.

Without water, there would be no life. Almost all biological processes in the cells of life forms and plants can only take place in an aqueous solution. In most of these processes, small molecules – called ligands – migrate like "keys" into matching "locks" on larger protein molecules, where they dock. This event then triggers signals or even the production of new substances.
The full role that water plays in these processes has never been fully known. Is it merely a passive transport medium, or does it perform other functions as well?
Physicists working with Prof. Dr. Joachim Dzubiella of the Institute of Soft Matter and Functional Materials of HZB and of HU Berlin studied this question using computer simulations of a model system. It turns out that water can actively influence the docking speed by subtle interactions with the geometry and surfaces of the molecules. This insight is new and could be of great interest for the targeted development of active pharmaceutical ingredients.



The motion and forces between water molecules (red-white), round ligands (green) and a water-repelling hollow pocket in a protein molecule were calculated in a computer simulation.

Water motion influences ligands

Together with colleagues from TU München, UC San Diego and the University of Utah, Dzubiella modelled the way in which a small ligand molecule docks into a kind of pocket in a protein, and calculated the motion and forces during this process. The team assumed a hydrophobic surface of this protein pocket. "Naturally, a number of water molecules also manage to get into the protein pocket," reports Dzubiella. "But they are repelled by the hydrophobic surface, and thus create a tiny wave, which in turn catches the ligand molecules in the vicinity." The geometry of the protein pocket determines how forceful these water fluctuations will be and whether they tend to hinder or perhaps even accelerate the ligand molecules nearby.
"If we wish to develop active ingredients that dock onto specific, targeted molecules in cells where they are supposed to trigger or prevent certain processes, then we must understand the process much more precisely than before," Dzubiella reasons. Indeed, with his work, he has delivered the first clues already.
arö

Proc. Natl. Acad. Sci. USA (DOI: 10.1073/pnas.1221231110): Solvent fluctuations in hydrophobic cavity–ligand binding kinetics, P. Setny, R. Baron, P. M. Kekenes-Huskey, J. A. McCammon and J. Dzubiella

POLYSACCHARIDE INCREASES JOINT STABILITY

HZB scientists working with Dr. Roland Steitz studied the behaviour of a boundary layer resembling that which exists in the joints of mammals. Their results could help **improve prostheses**.

The joints of humans and animals are complex structures. At the ends of bones that meet at a joint is a layer of cartilage on which lies a final lipid layer made up of only a few membranes. The joint capsule surrounding the joint is filled with joint fluid (synovial fluid). The synovial fluid, which ensures the joint remains properly lubricated, consists largely of water, but also contains the polysaccharide hyaluronic acid. Exactly how this lubrication in the joint works on the molecular level, at the boundary layer between the lipid layer and joint fluid, has long been a puzzle – one which scientists at Helmholtz-Zentrum Berlin are currently working on solving.
To study such a joint system using the neutron reflectometer at BER II, Roland Steitz and colleagues covered silicon, instead of bone, with a lipid layer and used heavy water, D_2O, as the joint fluid. They discovered that even a slight elevation of temperature to 26 degrees Celsius caused the lipid layer to detach – a process that would have painful consequences in a real joint. "In the second experimental set-up, we studied the interaction between hyaluronic acid in heavy water and the lipid layer. The boundary layer forms a so-called hydrogel, which you can imagine to be like a sponge. The lipid layer swells to four times its original thickness and becomes additionally cross-linked due to the incorporated hyaluronic acid. The hydrogel thus forms a buffer that protects the cartilage and bone," Steitz explains. Furthermore, the swollen lipid layer remains stable even as temperature increases. In further tests, they shall be studying the behaviour of the boundary layer at the hydrostatic pressure that builds up inside a joint as it moves. The results could help improve the coating of joints in prostheses, making them wear-free and stable over a longer time. *cn*

Biochimica et Biophysica Acta 1818 (2012) 2648–2659 (DOI: 10.1016/j.bbamem.2012.05.022): Impact of a model synovial fluid on supported lipid membranes, M. Kreuzer, M. Strobl, M. Reinhardt, M.C. Hemmer, T. Hauß, R. Dahint, R. Steitz

PING-PONG MAINTAINS ORDER

A research group at HZB led by Dr. Dimitri Argyriou has found the reason behind the stable structure of a certain crystal.

When an international research group at HZB studied a crystalline compound of terbium, iron and oxygen by neutron scattering, they made an astonishing discovery: at temperatures of around three kelvins and in an external magnetic field, the diffraction patterns from the material of chemical formula $TbFeO_3$ revealed an unusual structure. The experiments showed that, near absolute zero, the crystal divides into ordered magnetic domains. The gap between the walls of these regions is 170 ångströms (10^{-10} metres). Calculations the researchers performed suggest that the domain boundaries are kept at a distance by processes resembling the interactions inside atomic nuclei – and more specifically the Yukawa potential between protons and neutrons. These forces named after Japanese physicist Yukawa Hideki are mediated by exotic particles called pions. Playing the role of pions in the $TbFeO_3$ crystal are so-called magnons, which are excited magnetic states of the terbium spins. These are exchanged in a kind of magnetic ping-pong between the domain walls, thereby producing a repulsive force and keeping the structure stable.

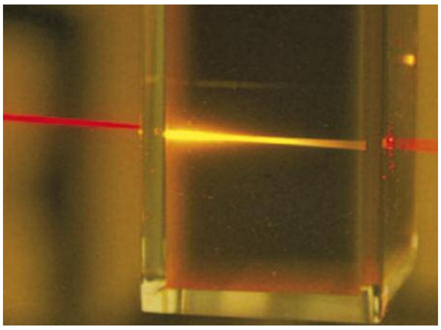
rb

Nature Materials 11, 694–699 (2012), (DOI: 10.1038/nmat3358): Solitonic lattice and Yukawa forces in the rare-earth orthoferrite $TbFeO_3$, S. Artyukhin, M. Mostovoy, N.P. Jensen, D. Le, K. Prokes, V.G. de Paula, H.N. Bordallo, A. Maljuk, S. Landsgesell, H. Ryll, B. Klemke, S. Paeckel, K. Kiefer, K. Lefman, L. Theil Kuhn & D.N. Argyriou

TURBO FOR SOLAR CELLS

In laboratory tests on solar cells, an international research group revealed how **energy losses** can be avoided in the conversion of light into electricity.

Modern silicon solar cells achieve a maximum efficiency of around 25 percent. Researchers around the world are racing to boost this efficiency even further. Yet a natural limit exists at around 30 percent because the laws of physics prevent solar cells from absorbing light of energies below a certain material-specific limit. The energy of this low-energy light is therefore lost. Scientists from Sydney University and HZB have found a solution to the problem with so-called photochemical upconversion: Two energy-poor photons that would normally be ineffective in the solar cell are merged into one energy-rich photon, which can then contribute towards the electricity yield.
"The solar cell efficiency boost may still be low, but the path to further improvement is now clear," says project head Dr. Klaus Lips of the HZB Institute for Silicon Photovoltaics. "The concepts for this were developed in close collaboration between Sydney and HZB." The biggest advantage of this approach is that no new solar cells would need to be developed; rather the mere addition of the ucoverter would in principle boost the efficiency on its own. "Just as you build a turbo into a car to make it go faster," Klaus Lips explains. *cn*



Red light from a laser pointer is converted into higher-energy yellow light as it passes through the liquid photochemical upconverter.

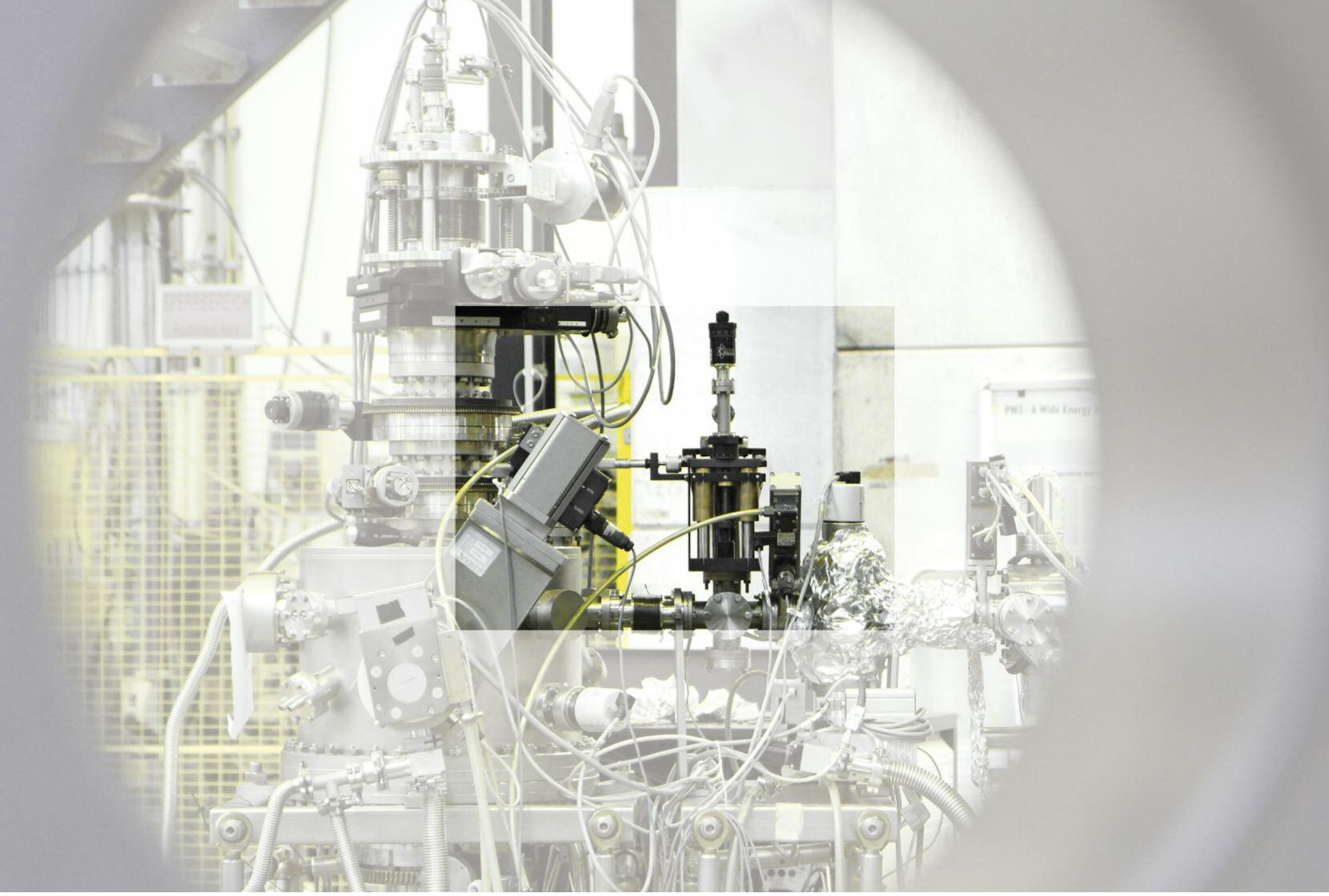
Proc. Natl. Acad. Sci. USA (DOI: 10.1073/pnas.1221231110): Solvent fluctuations in hydrophobic cavity–ligand binding kinetics, P. Setny, R. Baron, P. M. Kekenes-Huskey, J. A. McCammon and J. Dzubiella

PUZZLING STRIATIONS

Scientists working with Dr. Christian Schüßler-Langeheine have discovered puzzling striations in superconductors. This could be the key to tailored superconductors.

Superconductors are materials that lose all electrical resistance and therefore conduct electricity without any loss below a certain characteristic "transition temperature". Unfortunately, this transition temperature is usually very close to absolute freezing point, which makes practical applications very difficult. A so-called high-temperature superconductor, which loses all electrical resistance far above absolute freezing point, can be produced from the copper compound lanthanum cuprate with various properties by inserting metals such as barium or strontium in a targeted manner. Yet researchers are still unsure as to exactly why this compound becomes superconducting. Using X-ray and neutron experiments, HZB scientist Dr. Christian Schüßler-Langeheine showed that after doping with metals, lanthanum strontium cuprate develops magnetic and electric striations similar to those found in other superconductors. They arise when electrically charged, non-magnetic copper ions arrange themselves into regular stripes, and the researchers believe these stripes present a hindrance to superconductivity. Interestingly, however, further investigation showed that this structure disappears below a certain material depth. Why this is so remains to be seen. The physicists now hope to glean how important these charge striations are to superconductivity from the information gained from lanthanum strontium cuprate. *cn*

Nature Communications, (DOI 10.1038/ncomms2019): Charge stripe order near the surface of 12 percent-doped La_2-xSrxCuO_4, Wu et al.



JOINT VENTURES

The HZB department "Functional Materials", headed by Prof. Dr. Matthias Ballauff, has been involved in the **graduate school "SALSA"** of Humboldt Universität zu Berlin since November 2012 and will be supervising a doctoral student in the scope of this programme. The graduate school "SALSA – School of Analytical Sciences Adlershof", of the joint federal and state excellence initiative, advertised the first 15 doctoral fellowships in November, for which applicants were able to apply until December 2012.

The **Joint Berlin MX-Laboratory** founded at the electron storage ring BESSY II in 2010 by HZB, Freie Universität Berlin, Humboldt-Universität zu Berlin, the Max-Delbrück Centrum and the Leibniz-Institut für Molekulare Pharmakologie (FMP) will continue its work for at least five more years until the end of 2017. In the scope of this cooperation, HZB has provided the joint laboratory for crystallography with two of its three crystallography measuring stations, each with three experimental stations.

In 2012, HZB supervised a postdoctoral fellow from the **Indira Gandhi Centre for Atomic Research** (IGCAR). The basis for this collaboration with the research institute in Kalpakkam in Southeast India is a cooperation agreement concluded in 2007 and extended in 2009 for the joint training of PhD students and employment of postdocs. The purpose is to allow Indian scientists to stay at HZB for at least one year. HZB has had a similar agreement with the Bhabha Atomic Research Centre (BARC) near Mumbai since 2010.

LONG-TERM OUTLOOK

Charité Berlin and HZB shall continue their collaboration on **eye tumour therapy** indefinitely. The two-thousandth patient was treated with proton therapy in 2012.

Left to right: Martin Jermann, Prof. Dr.-Ing. Anke Kaysser-Pyzalla, Cornelia Yzer, Prof. Dr. Ulrich Frei, Prof. Dr. med. Antonia M. Joussen and Dr. Jutta Koch-Unterseher.

Charité Berlin and Helmholtz-Zentrum Berlin have been using proton beams to treat patients afflicted with eye tumours since 1998. In 2007, Charité assumed responsibility for this special therapy, to the great benefit of the patients. The contract to continue this proton therapy and to operate the corresponding accelerator facility was accordingly extended indefinitely by both parties at the end of 2011. That means hope still exists for the 500 to 600 people each year in Germany who are diagnosed with a malignant choroidal melanoma to undergo successful treatment. In more than 97 percent of cases, the tumour can be fully destroyed by this proton therapy. Most of the time, not only can the eye be saved but also a satisfactory degree of sight.
HZB und Charité celebrated the two-thousandth patient treated at HZB's Wannsee facility with a special colloquium on 11 October 2012. "The high quality of both the proton beam and the medical care are important to the success of the therapy. HZB and Charité are exemplary in Germany for this partnership," says senator for science, technology and research Cornelia Yzer. "We are proud that HZB can make this contribution to successful radiotherapy," asserts Professor Dr. Anke Kaysser-Pyzalla, scientific director of HZB. "It is a major scientific challenge to continually improve accelerator technology and positional accuracy for the good of the patient." This is one of the duties of HZB's Proton Therapy department, headed by Dr. Andrea Denker. She will be ensuring the facility continues to produce a proton beam adapted optimally to these therapy needs.

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GREATER EFFICIENCY WITH SCALENANO

The European Union is funding the thin-film solar cell project "Scalenano" involving 13 European research groups including HZB and FU Berlin. Funds exceeding ten million euros have been approved for developing chalcopyrite solar cell technology up until 2015. Among the chalcogenides, copper-indium-gallium-diselenide (CIGSe) is the material that achieves the highest degree of efficiency. So far, the compound has mainly been applied as micrometre-thin layers onto glass or foil using a vacuum-based coating technique. One aim of the "Scalenano" project is to develop new, eco-friendly and more affordable production techniques that do not require a vacuum. Dr. Thomas Unold and his HZB group will be addressing quality control and process monitoring in this respect, for which the researchers are developing novel analytical methods for characterising the solar cells during the manufacturing process.

In the new research strategy, thin-film absorber materials will also be combined with nanostructured, transparent conductive oxides (TCO for short). With this priority, the group of Prof. Martha Lux-Steiner and Dr. Sophie Gledhill of Freie Universität Berlin and HZB are working on adapting, optimising and optically modelling chalcogenide solar cells that additionally contain zinc oxide nanoarrays.

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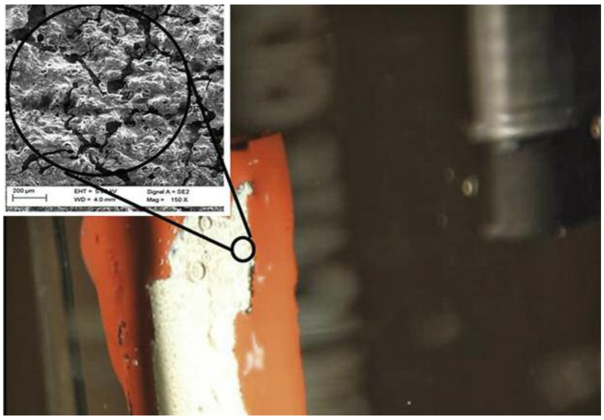
SUNLIGHT TO HYDROGEN

Scientists at HZB have tested a new hybrid material for hydrogen production in the collaborative project **“Light2Hydrogen”**.



Graphitic carbon nitride films deposited onto p-type CuGaSe2 thin films can be used successfully as photoelectrochemical components of photocathodes for hydrogen production from sunlight.

Using sunlight to produce hydrogen would be the ideal solution for storing solar energy. Yet there is still a lack of mature material systems for the production process of photochemical electrolysis, i.e. photoelectrochemical production of hydrogen by splitting water into its components oxygen and hydrogen. The process requires semiconductors immersed in water that absorb light and use its energy to bring charge carriers to the semiconductor material’s surface to make the photoelectrolysis happen. The ideal semiconductors would naturally be silicon or chalcopyrite, as used in photovoltaics. However, silicon and chalcopyrite semiconductors corrode immediately when immersed in water, rendering them useless. Researchers are therefore looking into other semiconductors, for instance the polymer carbon nitride. Until now, this substance had only been studied in powder form. Scientists working in the BMBF collaborative project

NEW MATERIALS FOR PHOTOVOLTAICS

The Helmholtz Association is funding research into renewable energies with three new Energy Alliances. HZB is involved in one of these.

Helmholtz-Zentrum Berlin, Forschungszentrum Jülich, Humboldt Universität Berlin, the University of Potsdam and Freie Universität Berlin form one of the three Energy Alliances called into being by the Helmholtz Association in 2012. The aim of this Energy Alliance, named “Inorganic/Organic Hybrid Solar Cells and Technologies for Photovoltaics”, is to promote targeted research into materials in the energy supply sector. The projects will be funded for three years, whereas research is also planned to continue beyond these three years.
The focus will be on combining inorganic semiconductors such as silicon, copper-indium-sulphide/selenide or gallium-arsenide compounds with organic materials that are also capable of converting sunlight into electric energy. However, each material class has its own downside. Production costs are relatively high for inorganic semiconductors, for instance, while organic solar cells made of small molecules or polymers offer relatively low efficiencies. Combining inorganic and organic materials into so-called hybrid solar cells could solve these problems.

Improving solar cell arrangements

The Helmholtz Energy Alliance of the Berlin, Potsdam and Jülich partners is pursuing this objective. It combines the expertise of each establishment on these two entirely different material classes. The researchers are focussing on processes that so far limit the efficiency of electricity generation at the interfaces between inorganic semiconductors and organic materials in these solar cells. One of their approaches to boosting efficiency is to create targeted nanostructures in these hybrid cells, bearing in mind that the manufacturing costs of all new synthetic methods must be kept low. One method is to introduce inorganic nanoparticles and nanowires into organic materials, for example. Another promising method is to embed organic semiconductors between inorganic nanocolumns.

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"Light2Hydrogen" have for the first time successfully deposited the polymer carbon nitride onto chalcopyrite and silicon and tested it. They proved that carbon nitride films on chalcopyrites or silicon can be successfully used as a component of photocathodes for light-induced hydrogen production. "If we wish to contribute towards developing new energy supply concepts with our research, we will have to enhance our processes to make them industrially applicable later on," explains PD Dr. Thomas Schedel-Niedrig, who heads the project at HZB.

The prospects of this happening are good: in 2012, HZB was admitted as a project partner into the DFG priority programme "Fuels Produced Regeneratively Through Light-Driven Water Splitting: Clarification of the Elemental Processes Involved and Prospects for Implementation in Technological Concepts" (SPP 1613). The aim of this programme is to efficiently make sunlight useful for hydrogen production on chalcopyrites and chalcopyrite solar cells, or alternatively for oxygen production on tantalum oxynitrides. *cn*

FULL CAPACITY FOR SMALL MODULES

The Photovoltaic Competence Centre Berlin (PVcomB) has brought two new facilities into operation for producing **thin-film solar modules**.

The Competence Centre Thin-Film- and Nanotechnology for Photovoltaics Berlin (PVcomB) – an initiative of Helmholtz-Zentrum Berlin and Technische Universität Berlin – has upgraded its two research lines for thin-film silicon and copper-indium-gallium-selenide (CIGS) solar modules. In 2012, together with partner Leybold Optics GmbH, it commenced full production of 30-by-30-centimetre modules on two inline sputter facilities. "Thin-film technology is being constantly advanced in the laboratory. It has to reach industrial maturity as quickly as possible," Dr. Rutger Schlatmann, head of PVcomB, summarises the mission of the competence centre. On two industrial reference lines, scientists and technicians are working on solving problems of industrial production. At the same time they are developing and testing alternatives from pure research.

Dr. Bernd Stannowski (left) and Dr. Sven Ring of PVcomB in front of the sputter lines of Leybold Optics.

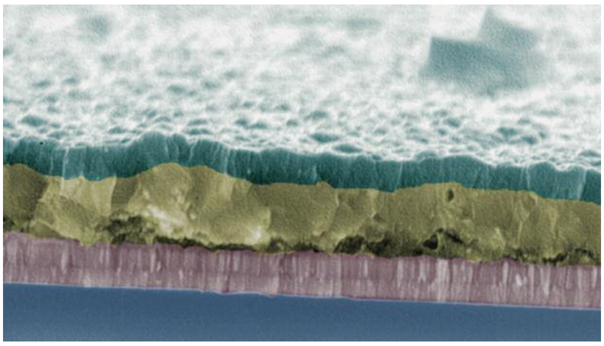
Rapid translation from research to industry

With the Leybold Optics sputter lines now in full operation, the competence centre can carry out the entire module production, from cleaning the glass to encapsulating the modules, at a glass size of 30 by 30 centimetres. On one of these sputter lines, in the thin-film silicon reference line, PVcomB can now produce its own layers for front-contact and back-contact systems. The second facility, in the CIGS reference line, employs the so-called sequential method for conversion of the absorbers for CIGS solar modules. "With our inline sputter facilities, we satisfy the high demands of PVcomB to produce CIGS and thin-film silicon solar modules in a state-of-the-art environment," announced Patrick Binkowska, manager of the Division Glass & Solar, Leybold Optics, during commissioning of the facil-ities at PVcomB. "At the same time, this cooperation gives us the chance to learn from PVcomB's experience. Insights from it will flow into the continuing advancement of our facilities." *cn*

TWO NEW VIRTUAL INSTITUTES

HZB is intensifying its collaboration with universities with the two virtual institutes for **thin-film solar cells** and **topological quantum physics**.

Virtual institutes are an instrument the Helmholtz Association uses to initiate and consolidate the collaboration between universities and Helmholtz centres. They are jointly financed for up to five years before a decision is made as to whether the collaboration will continue. A good example are the two virtual institutes newly



Thin-film solar cells such as this CIS solar cell are the focus of one of the new Virtual Institutes at HZB.

installed at HZB, which commenced work in December 2012 and April 2013.

At the virtual institute "Microstructure control for thin-film solar cells", HZB scientists have been collaborating with colleagues from FU Berlin, TU Berlin, TU Darmstadt and other partners since December 2012. Their aim is to optimise thin-film solar cells for producing electricity from solar energy. Until now, no one has fully understood the interplay between the microstructure of the polycrystalline absorber layer and the electrical and optoelectronic properties in such solar cells. "With a theoretical understanding of these correlations, together with simulations and modelling, we intend to create highly efficient solar cells. We are working on two technologically well-established polycrystalline systems: silicon and copper-indium-gallium-selenide ($Cu(In,Ga)Se_2$)," says Susan Schorr, professor at FU Berlin and head of the crystallography department at HZB.

Research for quantum computers

At the virtual institute "New states of matter and their excitations", which commenced work in April 2013, HZB is joined by scientists from FU Berlin, the MPI for the Physics of Complex Systems in Dresden, TU Dresden, the University of Göttingen and TU Dortmund. They are investigating the collective behaviour and new phases of matter. The background is the incredible diversity of metallic, magnetic and superconductive compounds that have been delivering unexpected results in pure research and materials sciences for decades. Such systems form the basis of countless technical applications that shape our present lives. A systematic understanding of new phases is therefore the key to long-term technological innovation such as the search for quantum computers. The virtual institute aims at bringing together leading scientists to take up this challenge.

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NEW PLATFORM FOR DETECTOR SYSTEMS

The Helmholtz Association has started a new research programme with the involvement of HZB.

The objective is to find technologies for building and networking novel detectors for photons, neutrons and charged particles, to optimise data transfer and analysis, and to develop and build exemplary detector prototypes. HZB is developing neutron and photon detector systems as well as intelligent, programmable data acquisition hardware. "An important issue in neutron research is replacing helium-3 in the detectors," says Dr. Thomas Wilpert, who is coordinating the neutron detector development. Helium-3 is highly sought after for research purposes, but is rare and expensive. HZB is therefore developing detectors that will use the more affordable boron trifluoride. These are needed for successfully upgrading the HZB time-of-flight spectrometer NEAT. A measuring station is also being set up at HZB's electron storage ring BESSY II for developing superior fast photon detectors.

cn

NEW LABORATORY FOR LIQUIDS

HZB and **FU Berlin** have opened a laboratory together for studying liquids and materials in solution using the latest methods.

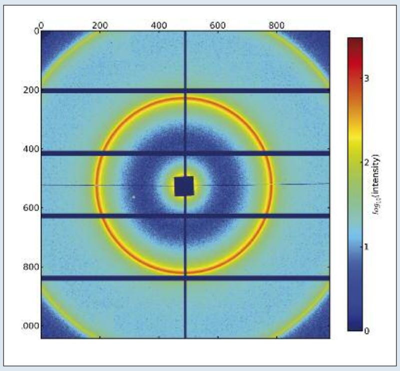
Be it modern metallic materials or biological substances such as proteins, Prof. Dr. Emad Flear Aziz, junior professor at the physics department of FU Berlin and group leader of the junior group Structure and Dynamics of Functional Materials at HZB, and his team have focussed their research on the structure and properties of materials in solution. Also of great interest to the researchers are the interfaces between two liquids that cannot be mixed. The laboratory, which opened in 2012 and is located at the electron storage ring BESSY II and at the laser laboratory of FU Berlin, gives them entirely new means for studying functional materials in solution. The new facility allows them to research using high-power lasers and synchrotron radiation, for example. Aziz will have 3.5 million euros over a period of five years for his work. Among other things, insights from materials research lead to innovations in medical technology and the energy industry for combatting diseases such as cancer and in developing solar cells, for example. At its opening, the scientific director of Helmholtz-Zentrum Berlin, Prof. Dr. Anke Kaysser-Pyzalla, stressed that the joint laboratory offers great opportunities for cooperation between scientists of both institutions as well as with research groups worldwide. She and the president of Freie Universität Berlin, Prof. Dr. Peter-André Alt, expressed the hope that more cooperatives of this kind would follow. *cn*

Prof. Dr. Emad Flear Aziz (right) setting up the new laboratory at the electron storage ring BESSY II.

TRACKING DOWN TINY BIOMARKERS

PTB has installed a new X-ray detector at BESSY II. It can help researchers decipher the triggers of diseases hidden within nanostructures.

Biomarkers can play an important role in the onset and treatment of disease. Yet it is still difficult for researchers to precisely measure the concentration and size of these miniscule particles which are found in all body fluids. An important step in this direction is the new vacuum-compatible, position-sensitive Pilatus detector developed by the Physikalisch-Technische Bundesanstalt (PTB). It was installed in PTB's laboratory at the electron storage ring BESSY II in 2012. The detector allows measurements using small-angle X-ray scattering at photon energies from 1.75 keV and therefore also at the absorption edges of biologically important elements such as phosphorus, sulphur and calcium. That arms the scientists with a machine that can measure the sizes of nano-particles which have so far been difficult to characterise. The PTB and HZB have been cooperating very successfully at Berlin-Adlershof for a long time. PTB has been running its own laboratory at BESSY II for its experiments since 1999 and cooperation in the field of small-angle X-ray scattering has been going on for six years. HZB furthermore ensures the continuing technical operation of PTB's "Metrology Light Source" of synchrotron radiation. *cn*



The Pilatus detector (on the right) is installed on the FCM beam tube of PTB with the ASAXS instrument of HZB.

FOUR MEASURING STATIONS FOR EMIL

The large-scale project EMIL for **researching into energy materials** is making progress – instead of three, it will now be endowed with four measuring stations.

With EMIL (Energy Materials In-situ Laboratory Berlin), HZB and the Max Planck Society (MPG) will be improving the research facilities for materials used in renewable energy generation as of 2015. The project revolves around building a new X-ray beamline at the synchrotron source BESSY II for analysing such materials.

The planned extension to BESSY II creates space for the labs SISSY I & II@EMIL and CAT@EMIL, as well as clean rooms and further laboratory space.

A total of four experimental stations shall be created at this beamline, where researchers will have simultaneous access to soft and hard X-rays, will be able to prepare their samples without interrupting the necessary vacuum, and will be able to study at the experimental stations SISSY I & II@EMIL (Solar Energy Materials In-Situ Spectroscopy I & II at the Synchrotron). While SISSY I@EMIL will serve for surface and interface analysis of solar energy materials prepared at the SISSY laboratory, an X-ray photoelectron microscope (X-PEEM) developed by Forschungszentrum Jülich is being set up at SISSY II@EMIL. The experimental station CAT@EMIL is being created for researching into catalysts required for producing hydrogen as a sustainably generated fuel. The measuring station PINK, which MPG will set up and operate within the existing hall of BESSY II, will then be available for non-resonant X-ray fluorescence. "Construction of the extension to BESSY II should begin in August 2013," says Prof. Klaus Lips, who is heading the project at HZB. "This extension will then house the laboratories SISSY I & II@EMIL und CAT@EMIL, a clean room, a chemistry lab and an electron microscopy lab where samples can also be prepared with a focussed ion beam." EMIL should be operational by 2015.

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BREAKTHROUGH AT THE PHOTOINJECTOR

Helmholtz-Zentrum Berlin is successfully enhancing innovative accelerator technology with its project *BERL*inPro.

The principle of ERL sounds simple enough: in the energy recovery linac prototype, electron packets are generated in an injector and accelerated in a superconducting linear accelerator (linac). The electrons can then be guided through so-called undulators (periodic magnet systems) in order to generate light of high brilliancy. After that, the electron packets which are continuously injected return to the linac where they are braked. This means practically all the energy is recovered, which in turn allows the acceleration of high currents.
HZB intends to put this simple-sounding principle into practice with B*ERL*inPro. The aim of the project is to accelerate an electron beam of high current (100 mA), small emittance and short pulse length at full energy recovery that is suitable for generating light of high brilliancy at user quality.
One important step towards the electron source needed for B*ERL*inPro was the successful commissioning and operation of two cavity resonators with a vapour-deposited lead cathode. The scientists are presently focussing on making further improvements to individual components of B*ERL*inPro, which theoretical model simulations show will already allow them to far exceed the original targets of B*ERL*inPro. The contracts for the superconducting accelerator structures of the injector and magnets have been awarded or will be awarded soon. The foundation stone for the B*ERL*inPro building will be laid in 2014. Up until its planned completion at the end of 2018 including energy recovery, the facility will be brought into operation one section at a time. Experimental enhancement of the key components will continue in parallel during this time.

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RECORD-SETTING MAGNET FOR NEUTRON RESEARCH

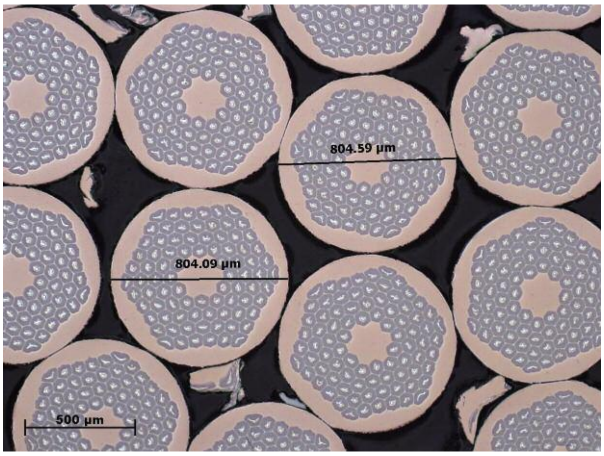
HZB is building the world's strongest magnet for neutron experiments – a **high-field magnet** which, when finished, will produce a field strength inside the sample in excess of 30 Tesla.

No neutron source in the world provides a magnetic field for experimentation stronger than 17 Tesla. Yet certain quantum effects only fully reveal themselves at extremely high magnetic fields, so combining neutron scattering with extremely high fields would be an ideal way to learn entirely new things about the nature of matter. In the project group for High Magnetic Fields (HFM), Dr. Hartmut Ehmler is coordinating the joint work of HZB and the National High Magnetic Field Laboratory (NHMFL), Florida, and other partners of the project. The heart of HFM is a so-called series-connected hybrid magnet system developed at NHMFL. It consists of normally conducting and superconducting coils mounted concentrically to one another and electrically connected in series so that the same 20,000-ampere current flows first through one coil and then through the other.

The superconducting coil is on the outside and produces a background field of 13 Tesla. Inside, the normally conducting (resistive) coil amplifies the magnetic field in the sample region to at least 25 Tesla and, when the facility is finalised, to fields above 30 Tesla – that is about one million times stronger than the earth's magnetic field. The sample itself sits in a relatively small space of a few centimetres between two conical apertures, through which the neutrons fired at the sample fly before colliding with the detectors.

Special sample environment

The superconductors of the outer coil are wires made of a niobium-tin alloy (Nb3Sn) which are cooled to 4 degrees kelvin, or minus 269 degrees Celsius, using liquid helium. The thermal radiation shields and high-temperature superconducting power lines of the superconducting coils are kept at a temperature of around 40 kelvin by helium gas. The inner, resistive magnet consists of a copper alloy in the form of so-called Bitter plates, which are designed to withstand the enormously strong forces. Bitter plates are circular metal plates stacked in a helical configuration. The inner copper magnets are cooled by water circulating through the many holes punched in the Bitter plates. The generated heat has to be removed through a high-pressure cooling circuit.



The windings of the external, superconducting coil are not made of a solid, homogeneous conductor, rather they consist of hundreds of very thin wires in which the extremely fine superconducting filaments are embedded in a matrix of stabilising copper. Pictured is a cross-section under an optical microscope.

The inner magnet fits precisely inside the superconducting coil and, at a power of 4 megawatts, produces a field of around 12 Tesla, which adds to the field created by the superconducting coil. This applies about 25 Tesla to the sample area. A superconducting coil cannot produce such a strong field on its own – this is only possible when elaborately combined with a copper magnet.

But a strong magnet alone is not enough for conducting research. The high-field magnet is, so to say, the special sampling environment of the corresponding neutron instrument EXED (Extreme Environment Diffractometer). This is an especially powerful time-of-flight spectrometer, which is currently being upgraded.

To ensure that the HFM and EXED will both fit together into Neutron Guide Hall II, the power and cooling water supply systems for the magnet will be kept in the neighbouring infrastructure building. The HZB experts in the HFM and EXED project groups have already concluded extensive tests and are ready to go. "We all hope the magnet can be delivered in autumn this year," Ehmler says. The subsequent assembly and commissioning will be one last major challenge for everyone involved. *arö*

TWO NEW INSTITUTES AT HZB

SINCE MID-2012, THERE IS THE NEW INSTITUTE **SOLAR FUELS AND ENERGY STORAGE MATERIALS** AND, SINCE JANUARY 2013, THE INSTITUTE **NANO ARCHITECTURES FOR ENERGY CONVERSION**.

Achieving a sustainable energy supply is a primary responsibility of our society. Researchers are therefore facing the challenge of developing real solutions to the energy demands of the future. In response to this, Helmholtz-Zentrum Berlin has established two new institutes to fortify its energy research. One is the institute Solar Fuels and Energy Storage Materials, founded on 1 July 2012 and headed by Dr. Roel van de Krol. At the same time as he was appointed head of the institute, the scientist was offered a chair at Technische Universität Berlin. Prior to this, Roel van de Krol was an assistant professor at the University of Delft in the Netherlands.

Prof. Dr. Roel van de Krol heads the new institute Solar Fuels and Energy Storage Materials at HZB.

In solar cells, sunlight is converted directly to electricity. The only successful means of storing this electricity so far is in large-scale facilities called pumped storage plants. A promising alternative for a sustainable energy supply is to convert sunlight directly into solar fuels. The simplest example of this is hydrogen, which can be obtained by splitting water molecules. Unfortunately, these methods are not yet fully mature. The direct production of fuels from sunlight is therefore the biggest challenge the institute at HZB will now tackle. The researchers are looking at producing hydrogen in a monolithic material system, a system in which the semiconducting absorber and the catalyst are integrated into a single structure.
The HZB researchers working with Roel van de Krol intend to develop novel complex metal oxides as cost-effective, chemically stable alternatives to conventional PV semiconductors. For this, carefully designed nano-architectures will be explored to overcome the intrinsically poor semiconducting properties of metal oxides.

PD Dr. Silke Christiansen, head of the new HZB Institute Nanoarchitectures for Energy Conversion since January 2013.

Expansion of solar energy research

Materials scientist PD Dr. Silke Christiansen has headed the new institute Nano Architectures for Energy Conversion at HZB since January 2013. This is yet another expansion of solar energy research at HZB. For establishing the institute, Ms. Christiansen will receive additional funding from the Helmholtz recruiting initiative of 600,000 euros per year over five years. Up until the end of 2012, Christiansen headed an independent scientific technology development group for "photonic nanostructures" at the Max Planck Institute for the Science of Light in Erlangen.
At HZB, she is developing novel material composites primarily for third-generation solar cells and solar fuels. Her work covers the entire research chain from modelling and simulation, characterisation and nano-analysis to the development of processes and components. "New nanostructured materials, bonded materials and composites will play a fundamental role in future concepts for obtaining and storing energy. I am delighted that I can press the research in this field ahead at full steam in the unique environment that Berlin and the Helmholtz Association offer," Christiansen enthuses.
The new institute complements and collaborates closely with the Institutes for Silicon Photovoltaics and for Solar Fuels. Christiansen furthermore collaborates with university workgroups and industrial partners. At the Wilhelm Conrad-Röntgen Campus in Adlershof, she and her team are involved in planning and outfitting the future Energy Materials In-situ Laboratory (EMIL). At the Lise-Meitner Campus in Wannsee, she is expanding HZB's expertise in electron microscopy.

cn

EUROPHYSICS PRIZE FOR ALAN TENNANT

THE PHYSICIST AT HZB RECEIVED THE PRESTIGIOUS RESEARCH PRIZE OF THE **EUROPEAN PHYSICAL SOCIETY IN 2012**.

There is a class of hypothetical particles that possess only one magnetic pole, either north or south, which physicists call magnetic monopoles. In the world of real matter, this is completely unusual since magnetic particles normally occur only as a dipole, namely possessing both a north and a south pole. Nevertheless, there are certain theories that predict the existence of monopoles as a source of magnetic fields. Among others, in 1931, physicist Paul Dirac derived from calculations that magnetic monopoles ought to exist at the end of so-called Dirac strings. These can be envisaged as tubes carrying the magnetic field. In 2009, Prof. Alan Tennant and colleagues successfully proved the existence of magnetic monopoles using neutron scattering at the Berlin neutron source BER II. For this discovery, Prof. Alan Tennant received the Europhysics Prize 2012 of the European Physical Society Condensed Matter Division (EPS CMD), worth 12,000 euros. He shared the honour with five other scientists from theoretical and experimental physics, who also published works on the detection of magnetic monopoles. The awarding ceremony was held on 5 September 2012 in Edinburgh. Tennant stressed above all the great significance of his research: “We are describing new fundamental properties of matter. These are generally applicable to materials with the same topology, that is materials with magnetic moments in the pyrochlore lattice. With such an insight, we can develop entirely novel materials in future.” *cn*

AWARD-WINNING PRESS

HZB’S PRESS OFFICE WON THE IDW PRIZE FOR SCIENCE COMMUNICATION FOR THE SECOND TIME.

Each year, the idw scientific information service bestows awards for the best press releases. The jury of journalists and scientists once again nominated a release from HZB in 2012. The first award went to the article by Franziska Rott on the “fastest film in the world”, about the research of Prof. Dr. Stefan Eisebitt, who developed a novel method for taking pictures on a molecular scale. The text won the vote of the idw jury for its “adept professionalism” and for the “scientific significance” of the topic as well as its “newsworthiness”. Marco Finetti, press spokesman for DFG, said at the award ceremony that HZB winning a second time is a remarkable double victory considering the competition from the 20,000 press releases that idw publishes each year. In 2010, Franziska Rott was a trainee in the HZB press office as part of her degree in scientific journalism at Technische Universität Dortmund, after which she started to produce press articles on a freelance basis. *cn*

Spokesperson Dr. Ina Helms and author Franziska Rott received the idw award for science communication for the best press release of the year from idw director Dr. Markus Zanner, Chancellor of Universität Bayreuth (from left to right).

QUICK NEWS

Henning Döscher, who earned his doctorate in 2010 at HU Berlin and the former HZB institute “Materials for Photovoltaics”, received the **SKM Dissertation Prize of the Condensed Matter Section** of the Deutsche Physikalische Gesellschaft (German Physical Society). He also received a **Marie Curie Research Fellowship** from the EU. This gives him the chance to make a two-year research stay at the National Renewable Energy Laboratory (NREL) in the USA.

Dominic Gerlach was awarded the **Student Award** for his article in June 2012 at the international Photovoltaics Specialists Conference (IEEE PVSC) in Austin, Texas. The PhD student, who has been researching in the Helmholtz junior research group of Marcus Bär since 2009, studied the electronic structure of the zinc oxide/silicon interface at BESSY II and at Spring-8 in Japan.

Dr. Stephan Werner, who works as a postdoc in the HZB Institute for Soft Matter and Functional Materials, received the **Werner Meyer-Ilse Memorial Award** at the 11th International Conference on X-ray microscopy (XRM2012) in Shanghai. In his doctoral thesis, Werner developed and characterised three-dimensional, nano-structured X-ray optics for the first time worldwide.

HZB GAINS TWO JUNIOR GROUPS

THE BMBF AND THE HELMHOLTZ ASSOCIATION ARE PROMOTING YOUNG SCIENTISTS AT HZB WITH TWO NEW RESEARCH GROUPS FOR **NANO- AND MICROSTRUCTURED SILICON COMPONENTS** AND FOR **NANO-OPTICAL CONCEPTS FOR CHALCOPYRITE SOLAR CELLS**.

As part of its programme “WING – Materials Innovations for Industry and Society”, the German Federal Ministry for Education and Research (BMBF) is funding the BMBF competition NanoMatFutur. With it, young scientists are given the opportunity to establish an independent junior group and conduct new interdisciplinary research into nano and materials technologies. One of the scientists receiving funding is Dr. Christiane Becker, who put together a new BMBF junior group at Helmholtz-Zentrum Berlin in December 2012 for developing nano and microstructured silicon components for applications in photovoltaics and photonics. Alongside two scientists from Switzerland and India, a PhD student and an engineer from a partner company are working in her junior group, which will be funded by the BMBF over the next four years with around 950,000 euros.
Under the title “Die Nano-SIPPE” (the Nanoclan) Becker has put together a detailed work programme with which she intends to achieve significant improvements in the production of new optical components made of thin, ultrafine structured silicon layers. “We are using processes that are industrially available for this. The aim of our research is to develop patents that the industrial partner and other companies can use,“ says Becker.

Dr. Martina Schmid

Dr. Christiane Becker

Junior group “Nano-Optical Concepts for Chalcopyrite Solar Cells”
In September 2012, the Helmholtz Association selected 14 young scientists to establish their own research groups at various Helmholtz centres. One of these is scientist Dr. Martina Schmid, who is putting together the junior group “Nano-Optical Concepts for Chalcopyrite Solar Cells” at HZB. Chalcopyrites are compounds of copper, indium, gallium, sulphur and selenium possessing characteristics that make them especially suitable for producing solar cells. Solar cells made thus achieve the highest degree of efficiency among the polycrystalline thin-film solar cells. Yet it is still a challenge to achieve high efficiencies at low cost. The solution could be so-called nano-optic solar cell architectures: such architectures would allow significantly thinner chalcopyrite layers and thus save on the rare and expensive heavy metal indium. At the same time, the nanostructures could maintain high efficiencies or achieve even higher efficiencies still by concentrating the light. Nevertheless, there is still no experimental proof of the concept to date, nor is there a comprehensive predictive model for ultra-thin chalcopyrite solar cells. This is exactly the challenge that Martina Schmid and her junior group at HZB will be tackling. *cn*

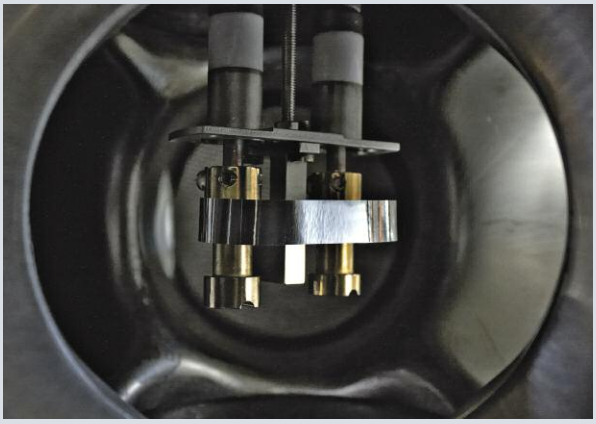
HZB-SCIENTISTS WIN TWO DGM YOUNG-TALENT AWARDS

The Deutsche Gesellschaft für Materialkunde (DGM) gave out its yearly young-talent awards in September 2012 at its annual conference in Darmstadt, distinguishing Martina Schmid and Melanie Timpel, two PhD students at HZB. Martina Schmid investigated for her doctoral thesis how tandem solar cells can be further improved. Tandem cells consist of two stacked thin-film solar cells that collect more light than a single cell on its own. By improving the structure of the top cell, Martina Schmid was able to raise the infrared permeability from 60 to 80 percent. Melanie Timpel’s thesis dealt with the refinement of aluminium alloys, where she used various methods to study the eutectic microstructure of the alloys at the atomic level. Her results made a significant contribution towards explaining the refinement mechanism.

IMPRESSIVE PHOTOS OF SCIENCE

DURING THE **HZB SCIENCE PHOTOWALK “AUGENBLICKE” (“MOMENTS”)**, 60 PHOTOGRAPHERS AIMED THEIR CAMERAS AT BESSY II AND SOME SOLAR ENERGY RESEARCH LABORATORIES IN AUGUST 2012. A JURY THEN CHOSE WINNERS FROM 400 ENTERED PHOTOS.

At the end of August 2012, professional and amateur photographers had the unique opportunity to explore the HZB premises in Adlershof for the space of an afternoon. They each photographed the synchrotron ring BESSY II, equipment used in HZB’s solar energy research, and various research stations from their own point of view. The participants were afterwards invited to submit their best photos for evaluation by a jury of four. “It is amazing how good the quality of the submitted photos is. We gained many new, interesting perspectives of our own research facilities,” says Ina Helms, head of the HZB communications department. Accordingly, it was no easy decision for the jury consisting of professional photographer Michael Setzpfandt, Anika Müller-Nähte of the graphics agency Schleuse01 and the two HZB employees Dr. Thomas Gutberlet, head of HZB User Service, and Ulrich Ewald, head of Administration. As the winning photo, the jurors selected “vacuum chamber at rest” by Lutz Bassin. It shows a vacuum preparation chamber with a manipulator for heating the sample to be studied. The jury also gave a special prize for best portrait photography to Christian Grozea, showing a former colleague working in the workshop. The three public choice awards, voted for by employees of HZB, went to two photos by Wolfgang Baier and Uwe Müller (tied for 1st place) and one photo by René Arlt (3rd place). The five award-winning photos were first revealed to the public along with 15 other exceptional photos in January 2013 as a display in the office building of BESSY II. *cn*



Winning photo of the HZB Science Photowalk: Lutz Bassin’s “Vacuum Chamber at Rest”.

IMPORTANT APPOINTMENTS

Prof. Dr. Rutger Schlatmann, head of the Competence Centre Thin-Film- and Nanotechnology for Photovoltaics Berlin (PVcomB), received the W3 professorship “Solar Cell Technology” at the Berlin University of Applied Sciences in June 2012. It is HZB’s first joint appointment with this university.

Prof. Dr. Roel van de Krol, who has headed the new HZB institute Solar Fuels and Energy Storage Materials since 1 July 2012, received at the same time a chair at Technische Universität Berlin (see page 46).

Prof. Dr. Bella Lake, head of the department Quantum Phenomena in New Materials received a W2 professorship at TU Berlin in July 2012. This appointment follows the junior professorship she obtained together with the head of the Helmholtz Young Investigator Group in August 2006 at TU Berlin.

Prof. Dr. Klaus Lips accepted the W2 professorship “Analytics for Photovoltaics” at the department of physics of Freie Universität Berlin and was officially appointed in December 2012.

QUICK NEWS

In 2015, HZB, together with the MPI of Colloids and Interfaces (MPI-KG) in Golm and TU Berlin, will be putting on the biggest **international conference on small-angle scattering – SAS 2015** – in Berlin.

The **Fifth Joint BER II and BESSY II Users’ Meeting** at HZB will take place from December 4th–6th 2013 in Berlin.

The conference **Science & Scientists at ESS** was held in Berlin on 19 and 20 April 2012. With over 300 scientists, it was the largest scientific conference to take place on the path to realising the European Spallation Source in Lund, Sweden. The conference provided a hub for discussion about the scientific possibilities of the neutron source, which will open in Lund in 2019.

Organisation Chart HZB

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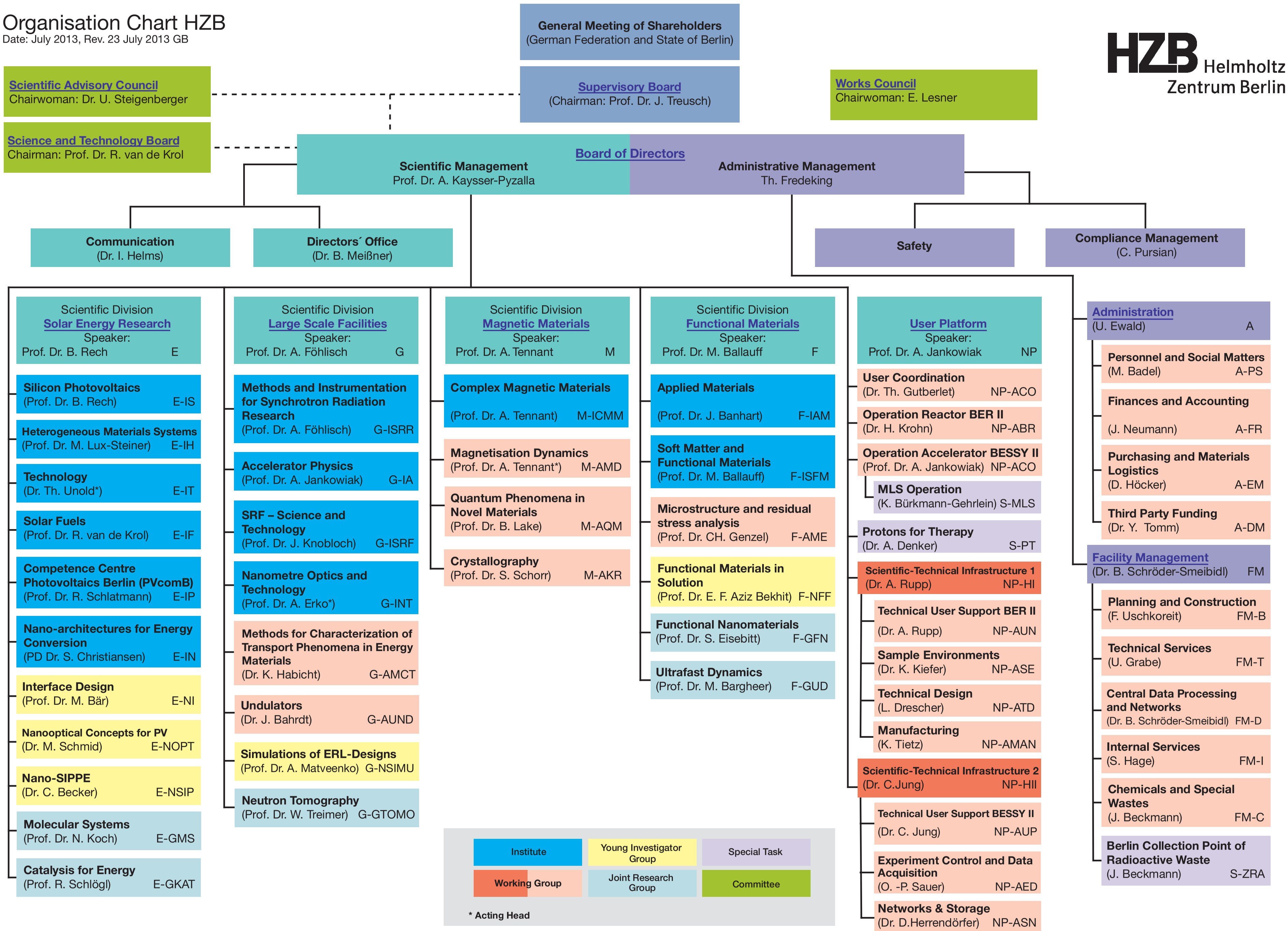

Site map
The Lise-Meitner-Campus with the research neutron source BER II is located at the HZB Berlin-Wannsee site, whereas the Wilhelm-Conrad-Röntgen-Campus with the electron storage ring BESSY II is located at the HZB Berlin-Adlershof site.

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