The Magazine from Forschungszentrum Jülich 01 | 2012

RESEARCH in Jülich

:: INSIGHTS INTO THE NANOWORLD

Ultrahigh-Resolution Microscope Achieves Resolution of 50 Picometres

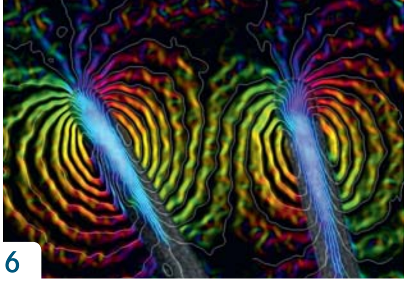
:: PEGASOS: A Research Airship

:: Innovative Microchips Transmit Signals from Living Cells

JÜLICH FORSCHUNGSZENTRUM

:: A LOOK AT THE DETAILS

A view inside Jülich's unique universal tool: the nano-spintronics cluster tool. Researchers from the Peter Grünberg Institute developed it to fabricate, image and investigate electronic nanocomponents for spintronics in an ultrahigh vacuum. Spintronics exploits not only the electronic properties of an electron but also the magnetic properties, and could provide us with an energy-saving option for information technologies in future.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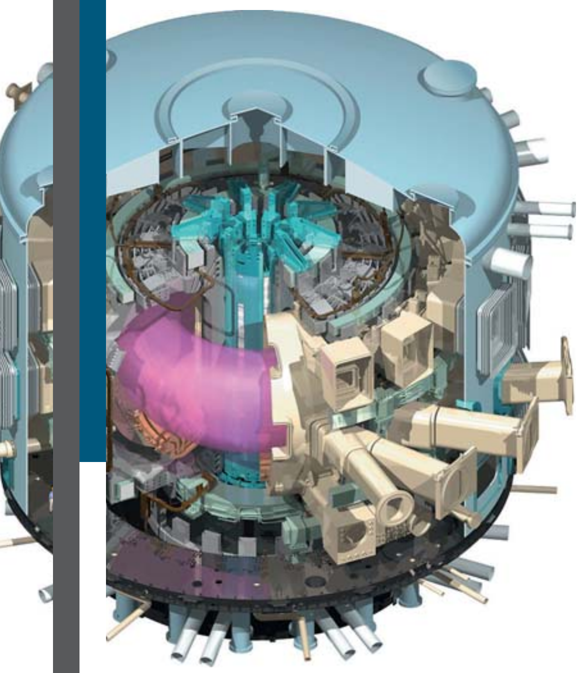


At the end of 2019, ITER in France is scheduled to go into operation and demonstrate the technological feasibility of fusion energy on a power-plant scale.

Jülich Know-How for Fusion Devices

Jülich scientists and engineers have designed and constructed key components for the inner wall of the vacuum vessel in the world's leading EU nuclear fusion experiment JET.

With the "ITER-like wall" made of solid tungsten, they are contributing to the success of the ITER international fusion reactor.

In the vacuum vessel, plasma is generated with a temperature of 100 million degrees. The scientists are investigating materials that can withstand this immense strain. Jülich has obtained in-depth scientific insights in this area and has developed unique techniques and technological components for fusion experiments.

The "ITER-like wall", the inner wall in the Joint European Torus (JET), was developed by Jülich scientists. It has a lamellar structure made up of over 9,000 individual components and withstands very high temperatures. In the JET vessel, the wall is located at those spots that are most exposed to the fusion matter, which has a temperature of millions of degrees. This Jülich design has paved the way for ITER's vacuum vessel and, ultimately, for a fusion plasma that generates energy. ::

Strategies for Fighting Forgetfulness

When thought process cease to work smoothly, the brain develops new communication strategies. This is the result of a study performed by Jülich researcher Dr. Heidi Jacobs based on her investigations at Maastricht University. For the study, Dr. Jacobs asked healthy volunteers and patients with incipient Alzheimer's disease to perform a mental rotation task. In so doing, she observed differences in the activity of the brain regions involved – the parietal lobe, a region that is strongly connected with the medial temporal areas, which are important for long-term memory.

Her amazing results: both groups were able to perform the tasks equally well. Apparently, brain regions not usually strongly associated with the task at hand step up their cooperation. The activity of other areas of the brain normally involved in solving the problem also increases. The brain uses this trick to continue to function in an optimal manner. In this way, the brain may delay the effects of the deterioration process that also occurs in Alzheimer's. The researchers hope that these insights will help them to understand dementia better and develop new approaches for treatment. ::

Information Codes in the Brain

Researchers from Jülich and Berlin have used mathematical models to discover that loop-shaped neuron clusters can take on an enormous range of patterns and thus create information codes. Such loops are fundamental structures in the human brain and play a role in the coordination of movements.

The computer model developed by Dr. Oleksandr Popovych at Forschungszentrum Jülich's Institute of Neuroscience and Medicine, together with his Jülich colleague Prof. Peter Tass, and Dr. Serhiy Yanchuk of Humboldt University Berlin, can vary the signal intensity and time within neuron loops.

The surprising variety of stable and dynamic information patterns provides important insights for understanding the inverse state of disturbed communication in the brain.

The Creation of Brain Waves

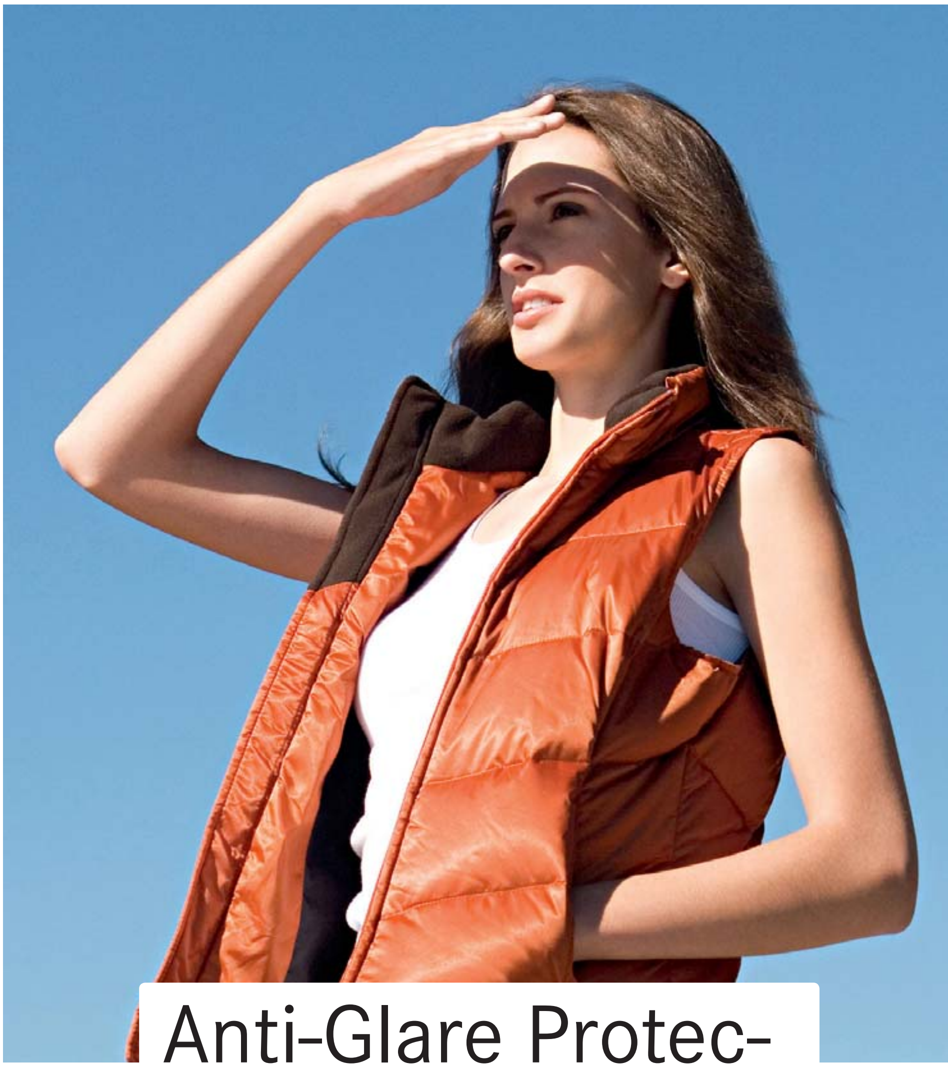
Scientists from Forschungszentrum Jülich and the Norwegian University of Life Sciences have developed a model that explains the correlations between the activity of neurons and measurable electrical signals.

Neurons generate electricity when they are active. During electroencephalography (EEG), electrodes measure the electrical signals, which can be assigned to various diseases, such as epilepsy. However, previously very little was known about the way they occur at the microscopic level in the brain cells' network.

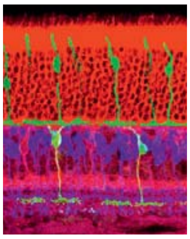
Prof. Markus Diesmann of the Institute of Neuroscience and Medicine was involved in developing the model, which provides a crucial result: the range of a measuring electrode is not a constant quantity, but rather is dependent on the activity of the neuron which itself influences the size of the area in the brain measured by an electrode.

The findings can be used to evaluate measurement values better in future in order to make more detailed diagnoses for patients with brain diseases such as epilepsy or Parkinson's and to select appropriate treatments. ::

Measuring electrodes record electrical signals in a "forest" of neurons.



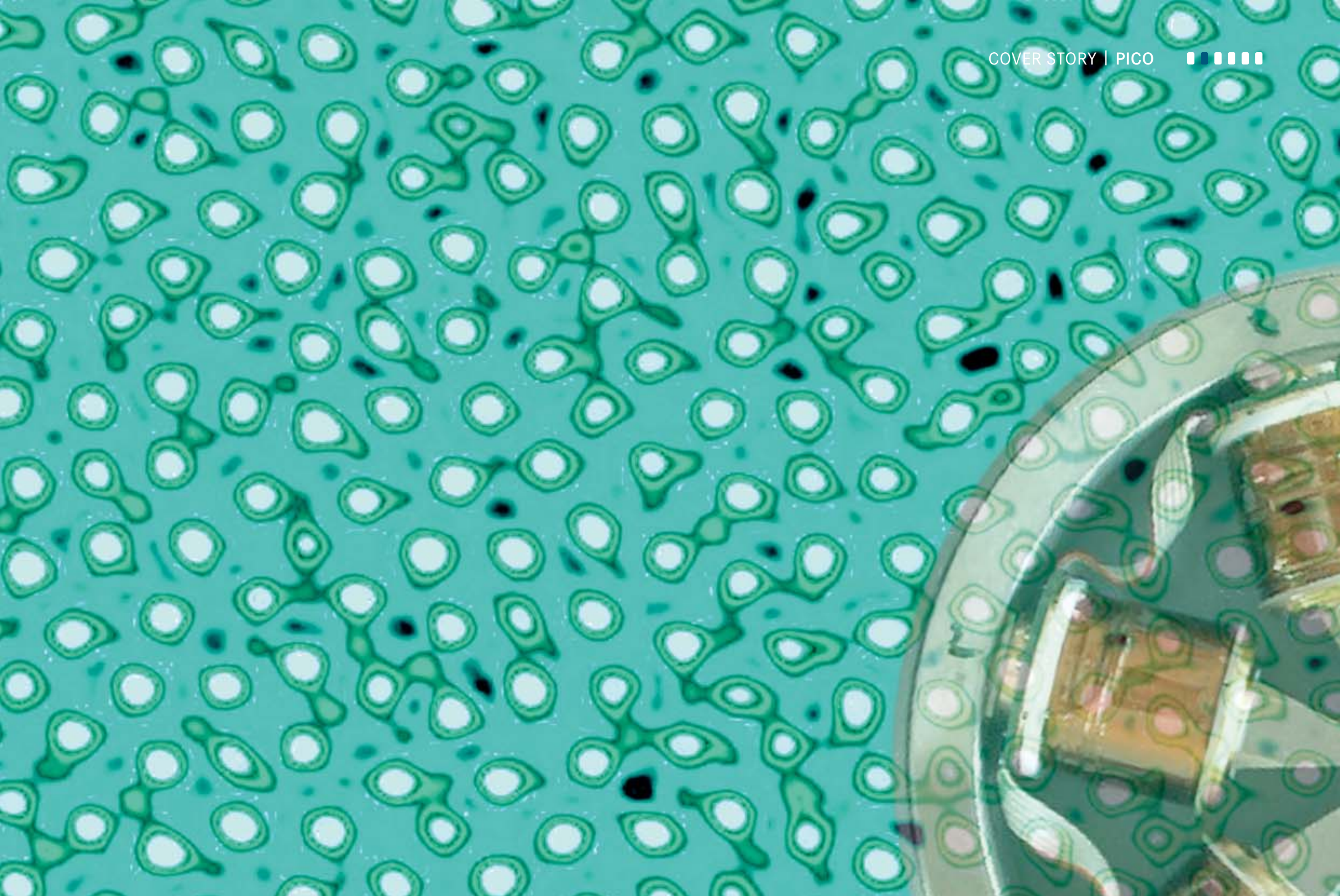
Anti-Glare Protection in the Eye



The human eye is highly adaptable. It can see just as well in harsh sunlight as during dusk or at night. To do so, it makes use of two sensitive types of sensory cells: cones for sunlight and rods for darkness. In a transition zone, for instance, at dusk, the two types of visual cells work in parallel.

Jülich researchers from the Institute of Complex Systems, along with colleagues from Tübingen, Oldenburg and Dublin, have now discovered how the eye ensures that two such different systems can interact optimally.

Since the rods send their signals to the same neurons as the cones, the sensitive rods would block the cones if there is a high incidence of light, which would result in sensitivity to glare. The scientists have now identified a molecular switch that, like an emergency brake, ensures that the neurons remain ready to receive incoming signals from the cones. Responsible for this is an ion channel, which is activated with increasing incidence of light. ::



:: Unique Insights into the Nanoworld

Using the best electron microscopes of our time, researchers at the Ernst Ruska-Centre (ER-C) are able to visualize the arrangement of atoms in a material and study them in great detail. This is crucial for the progress in materials science and nanotechnology, because the interaction between the atoms determines the properties of materials and components. ER-C, which is jointly operated by Forschungszentrum Jülich and RWTH Aachen University, has now added an ultrahigh-resolution microscope (PICO) that is unique in Europe to its range of instruments. In addition to spherical aberration, PICO corrects an additional lens error – chromatic aberration – and, in so doing, achieves a record resolution of 50 billionths of a millimetre.

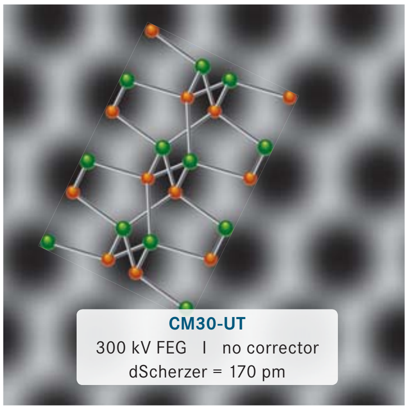
A simple mental experiment illustrates the tiny dimensions probed by scientists with their state-of-the-art electron microscopes. In order to visualize the atoms in a hair, with a diameter of around 1/20 millimetre, you would first have to blow up its cross-sectional area to at least the size of a football pitch. The thickness of a blade of grass on the pitch would then correspond to the diameter of the atoms you aimed to visualize individually.

However, after electron microscopy was invented in the 1930s, attempts to visualize atoms remained unsuccessful for decades due to lens aberrations that could not be corrected. "Although you have to keep in mind that in electron microscopes, no glass lenses are used, as in the case with optical microscopes. Instead, magnetic fields take on the function of the lenses," explains Dr. Karsten Tillmann, managing director of ER-C and scientist at Forschungszentrum Jülich's Peter Grünberg Institute 5. It wasn't until the 1990s that researchers from Technische Universität Darmstadt, the European Molecular Biology Laboratory in Heidelberg, and Forschungszentrum Jülich invented the "hexapole corrector", which was able to correct one of the lens errors. Its key elements are two components in which six (Greek: hexa) magnetic coils surround the central opening for the electron beam. "Equipped with this corrector, an electron microscope that was initially located in Heidelberg and later in Jülich was able to visualize the atomic structure of materials for the first time," Tillmann explains. Starting in 2004, gradually all leading manufacturers of electron optics began offering instruments with a corrector for spherical aberration. They achieve a resolution capacity of 80 picometres (1 picometre = 1 billionth of a millimetre). The resolution capacity is an indication of how far apart dots in a specimen may be from each other in order to still be visualized separately.

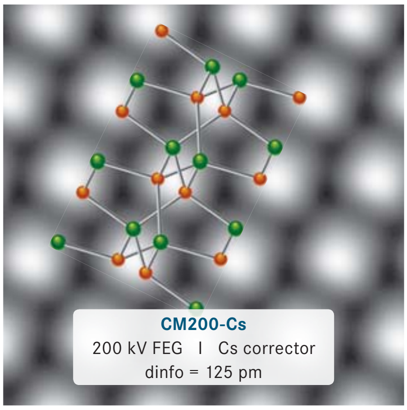
RESOLUTION: 50 PICOMETRES

For several months, in addition to three electron microscopes with a hexapole corrector, ER-C has also had an instrument that goes by the name of "PICO" at its disposal; PICO is also able to correct the second lens error – chromatic aberration. It is the only one of its kind in Europe and achieves a resolution

1992

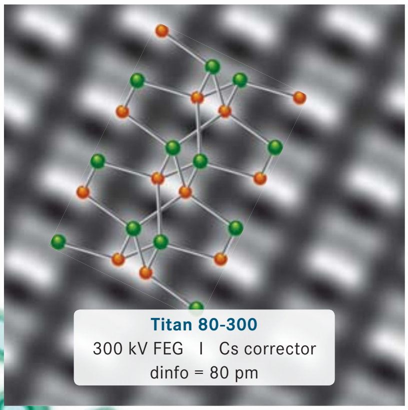


1998

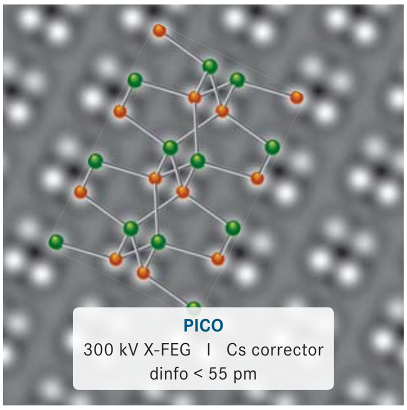


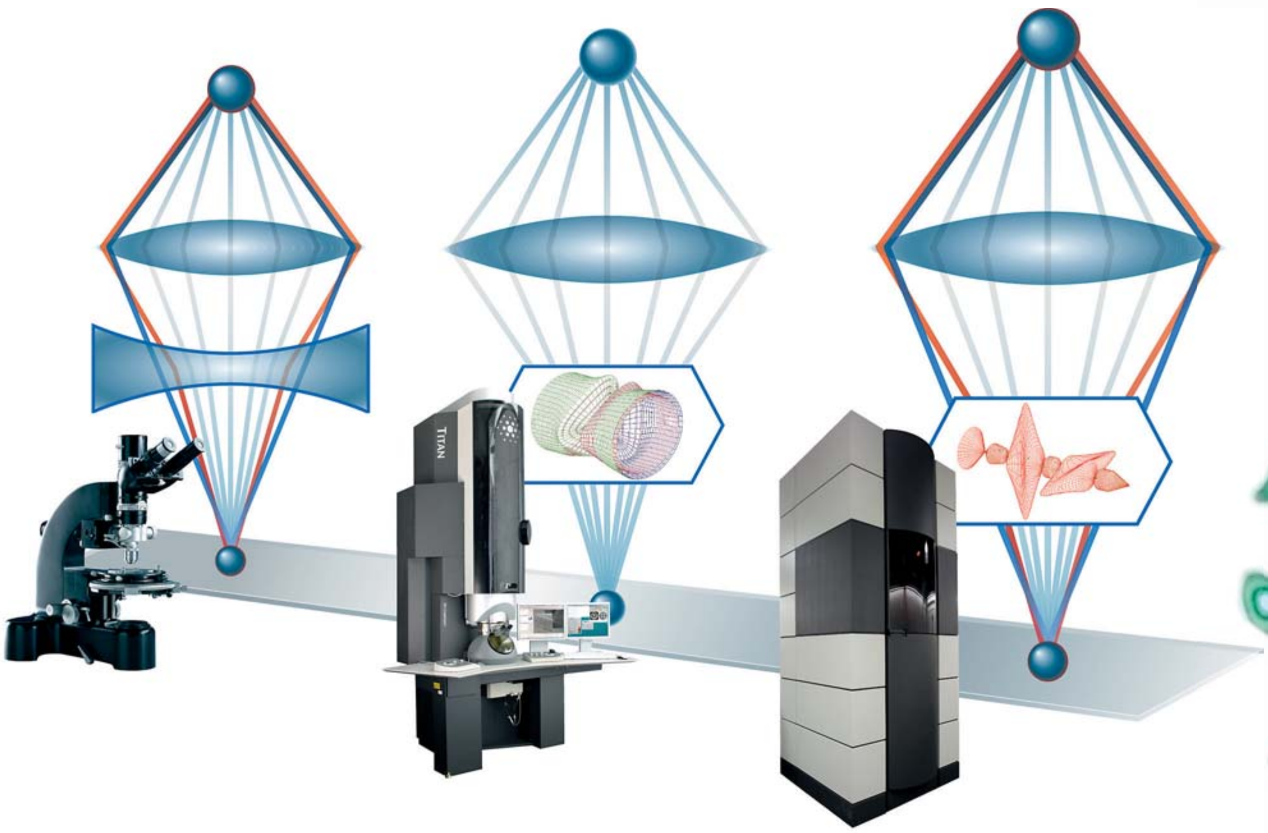
These simulated images of aluminium nitride illustrate how much resolution has improved with each generation of electron microscopes. Only PICO makes it possible to actually recognize atomic arrangements (red and green spheres).

2005



2012





In an optical microscope (left), a divergent lens ensures that imaging errors are corrected. Latest-generation electron microscopes (centre) can eliminate spherical aberration by means of a hexapole corrector. PICO (right) uses a system of magnetic and electrostatic multipole elements to also correct chromatic aberration.

of 50 picometres. “The higher resolution capacity will become particularly apparent when we have to use relatively low-accelerated electrons. This is the case for soft or biological materials, for instance, which are frequently sensitive to radiation,” says Prof. Rafal Dunin-Borkowski, one of the two directors at ER-C and also director of Forschungszentrum Jülich’s Peter Grünberg Institute 5. In addition to improving the resolution, this also increases the precision in measuring atomic distances and atomic displacement, from five picometres to merely one.

Even if improvements in the range of a billionth of a millimetre may seem to be minuscule, atomic displacements in this dimension are in fact essential for the electrical, optical, and other properties of materials. “Such tiny changes in the position of atoms determine the properties of modern transistors, for instance,” says Dunin-Borkowski. Ferroelectric data storage devices, such as those contained in chip cards or in some electronic car keys, are another example. If information is registered there, the position of the oxygen ions in the material shifts towards their neighbouring atoms by approximately 20 picometres. In addition, the effect of catalysts, which are used for around 70 % of all manufacturing processes in the chemical industry, is frequently based on very tiny changes in the position of the atoms near the surface of the catalyst.

“We are using electron microscopes to perform research on materials for CO_2-free power plants or for more powerful memory devices, for instance,” says Prof. Joachim Mayer, ER-C’s second director. Mayer, a physicist at RWTH Aachen University, adds, “For this reason, we use microscopes to meet global challenges like energy-efficient information technology or a climate-friendly energy supply.”

MEMBRANES AGAINST WARMING

ER-C scientists belong to the Jülich Aachen Research Alliance (JARA) comprising universities, research institutions, and industrial partners, which develops membranes for gas separation. Such membranes are used to decrease the carbon dioxide (CO_2) emissions of coal-fired and gas power plants, which significantly contribute to global warming. With what appears to be the simplest of all conceivable concepts, the off-gases from the coal or gas combustion are sent through a CO_2-permeable membrane that “sifts out” the greenhouse gas. It could then be stored underground. In fact, coal-fired power plants already exist in which a similar principle is used to scrub CO_2 by means of alkaline solutions. However, the technology is very complex, requires space the size of a football pitch and reduces the efficiency of the power plant by more than ten percentage points. “Two other methods that work on a similar principle have a higher potential for cutting down on CO_2. For these methods, you need membranes that separate oxygen from the air," explains Dr. Stefan Roitsch, scientist at ER-C.

In their quest for the most efficient membranes, the collaborating researchers fabricate a wide range of materials using a variety of methods. Afterwards, they test how well and how long they function under the conditions prevailing in a power plant. Thanks to the researchers and the electron microscopes at ER-C, they are not just groping in the dark when they seek to identify the reasons for the varying performance capacity of the materials. This is ultimately determined by the arrangement of the atoms, which is visualized by the electron microscope. In this way, the researchers at ER-C have studied samples of a material nicknamed BSCF, which in principle appears to be well-suited for separating oxygen and nitrogen at 700 °C to 900 °C.

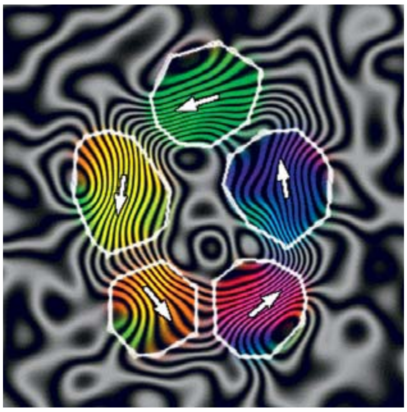
ENERGY-SAVING MEMORIES

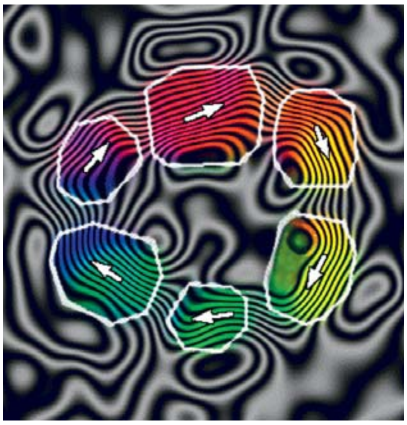
"During our research, we observed that at these temperatures, after several hundred hours, areas form in which the atoms are arranged differently than they were originally – with negative consequences for the oxygen conductivity of the material," Roitsch says. This has now given the researchers a starting point for improving the potential membrane material. For instance, they use chemical additives to prevent the atoms from rearranging themselves.

Another area studied by the scientists at ER-C involves materials for information technology, which has determined our everyday life and the productivity of industrial and service companies for a long time. In future, not only the processors, but also data storage systems will constantly become smaller, more powerful, and more energy efficient.

Especially for the investigation of ferroelectric materials, in which, contrary to today's computer working memory, data stored are preserved even after the computer is switched off, the scientists at ER-C working with former ER-C director and present JARA Senior Professor Knut Urban have gained substantial insight that has created a sensation among experts in the field.

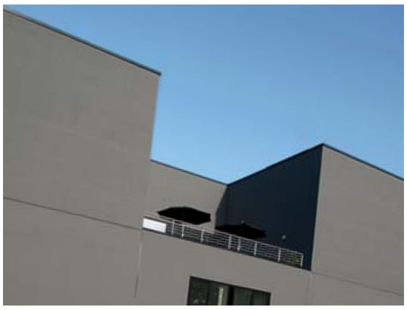
Today's computer hard drives are based on magnetic materials. Rafal Dunin-Borkowski, Urban's successor as ER-C director, has advanced electron holography for investigating magnetic materials and brought the know-how needed for this to ER-C. He says: "With specially equipped ultrahigh-resolution electron microscopes and certain imaging and evaluation techniques, the magnetic fields in these types of materials can be visualized with a resolution of only a few nanometres, a feat that cannot be achieved with any other method." In this way, he has already encountered structures in magnetic materials that are smaller than similar storage units in today's memory devices. ::





With specially equipped ultrahigh-resolution electron microscopes, magnetic field lines (black) and their direction (white arrows) can be visualized, here in a ring-shaped arrangement of cobalt particles (white border), a mere 20 to 30 nanometres in size. The self-organized ring-shaped structure is a candidate for the data storage system of the future, because it is smaller than the corresponding storage systems of today.

Ernst Ruska-Centre (ER-C)



With the Ernst Ruska-Centre (ER-C), Forschungszentrum Jülich and RWTH Aachen University operate a centre of excellence on the campus of Forschungszentrum Jülich for atomic-resolution electron microscopy and spectroscopy on the highest international level. ER-C develops scientific and technical infrastructure and methods for present and future materials research. At the same time, it is a national user facility for ultra-high-resolution electron microscopy. Fifty percent of the available measuring time is allocated to external users from universities, research institutions, and industry, based on scientific criteria.

→ *www.er-c.org*

"In-Depth Understanding"

Three questions for the directors of the Ernst Ruska-Centre.

Question: All kinds of methods are available for scientists to obtain information about the structure of the world in the micrometre and nanometre range. What can electron microscopy do that other methods cannot?

Mayer: Electron microscopy was invented to overcome the limits of optical microscopy. In fact, you wouldn't be able to visualize the transistors installed in today's laptops with an optical microscope, because they are too small. You also wouldn't be able to use an optical microscope to visualize the defects that – if they spread – cause plastic deformation of many materials. These are just two examples that demonstrate our need for electron microscopy to investigate the way components function or to study the properties of materials.

Dunin-Borkowski: Transmission electron microscopy provides information about the internal structure of materials. This distinguishes it from methods such as scanning tunnelling and atomic force microscopy. These two techniques are also commonly used to investigate the nanoworld, although they visualize only the surface of materials.

Question: So you buy the best possible electron microscopes, prepare a material specimen and then obtain the information you need. Is it really that easy?

Dunin-Borkowski: No, it isn't. High-resolution electron microscopy is certainly not a technology that functions perfectly just by pressing a button. In this vein, having a top-class instrument is no guarantee that you will perform top-class research. You need a great deal of knowledge and know-how to obtain and interpret images. By the way, that's one of the Ernst Ruska-Centre's key features. We develop the methods related to all aspects of correcting lens aberrations and for interpreting images. There is no other centre any place in the world that invests as much in this area.

Question: The Ernst Ruska-Centre is part of the Jülich Aachen Research Alliance (JARA). Why is it important for the Centre to be set up as a joint facility of RWTH Aachen University and Forschungszentrum Jülich?

Mayer: One research institution alone, even one the size of Forschungszentrum Jülich, cannot justify the acquisition of several aberration-corrected electron microscopes. After all, a microscope of this sort costs between four and nearly seven million euros.

Ultimately, the point is to get as much use out of the microscopes as possible. And the only way to do this is if you employ scientists who work on the methods, along with scientists who contribute research projects and applications. Then you have to train the early-career scientists to use the technology as well. One research institution alone can't afford to do this by itself. Within JARA, RWTH Aachen University and Forschungszentrum Jülich share what each institution can do best, which generates real added value. ::

Prof. Rafal Dunin-Borkowski (left) and Prof. Joachim Mayer.

PEGASOS:
Pan-**E**uropean **G**as-**A**ero**SO**ls-Climate Interaction **S**tudy

A Research Airship

In May 2012, the largest scientific mission to date involving a Zeppelin NT will be launched. The Jülich Institute of Energy and Climate Research (IEK-8) will coordinate the many experiments on board. The special feature: ZLT Zeppelin Luftschifftechnik in Friedrichshafen is building a new airship, just for research purposes.

The objective is to measure the composition of the air over the Netherlands, Italy, the Mediterranean, and Finland in several stages between May 2012 and June 2013. It's a megaproject that promises to provide science with important insights for air quality and climate research. It is part of the EU campaign PEGASOS, which involves twenty-six scientific institutions from throughout Europe.

SPECIAL EQUIPMENT FOR JÜLICH

The preparations for the measurement campaign are in full swing, not just at Jülich but also at ZLT Zeppelin Luftschifftechnik in Friedrichshafen. A Zeppelin NT used for advertising purposes in Japan between 2005 and 2010 was redeployed to Friedrichshafen. "NT" stands for "new technology", which comprises swivel-mounted propeller drives for this new generation of airships. ZLT is currently completely over-

The assembly of the new airship shell takes around four weeks. Employees at the airship manufacturer work by hand, attaching the tailor-made outer shell to over 4,000 points on the airship's lengthwise bar.

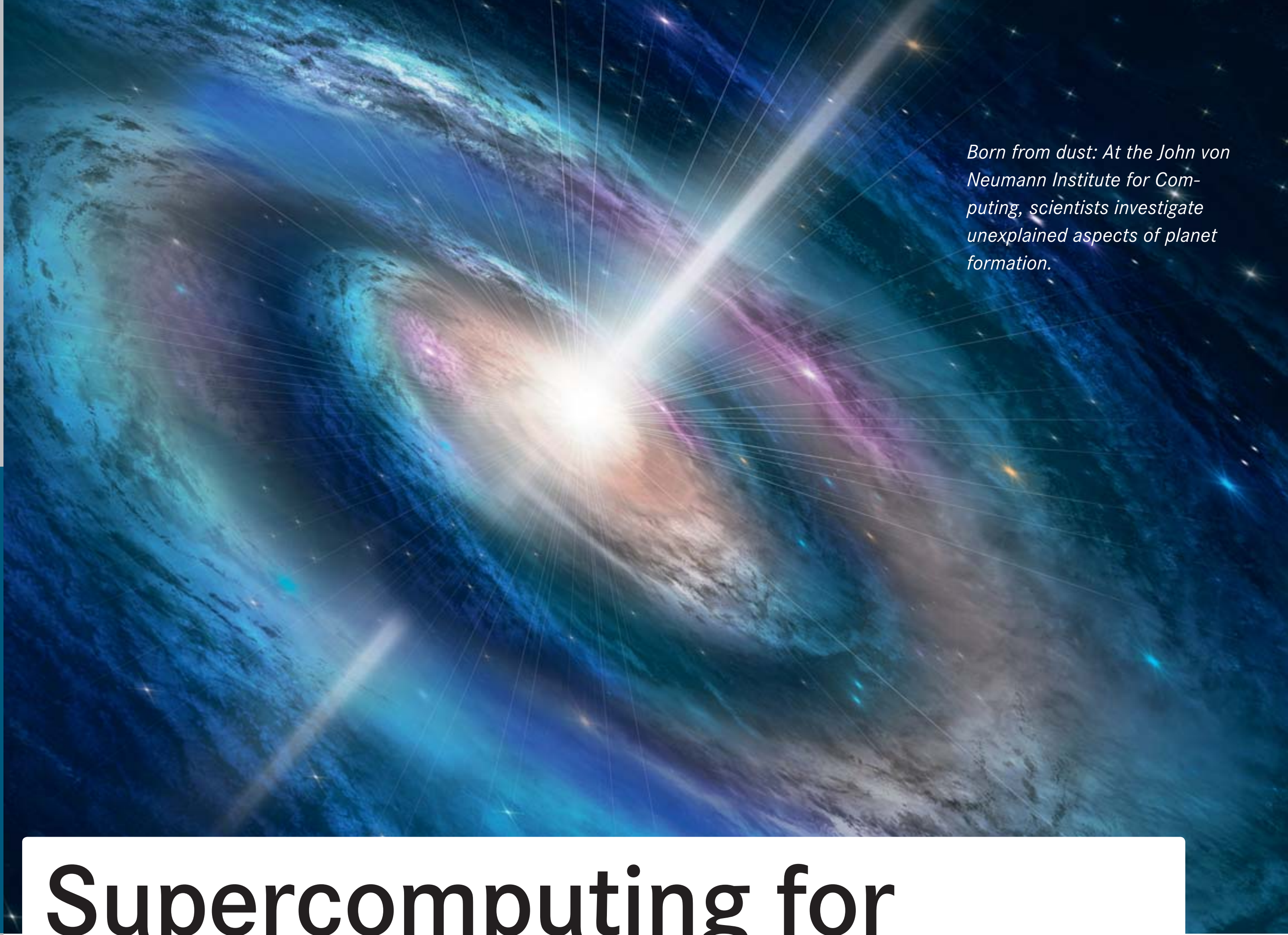
hauling the airship known as "Bodensee", rebuilding it and equipping it with state-of-the-art technology, so that it will be ready for action on time in spring 2012.

A special feature is the platform installed on top of the Zeppelin. It has a dead weight of around 130 kilograms and carries measuring instruments weighing around 350 kilograms. To bear the weight, the airship's internal structure was reinforced. "The flight properties are not compromised by this special structure," explains Dorit Knorr, spokesperson for the airship company. In addition, up to 500 kilograms of instruments are located in the gondola, although some of the instruments in the gondola can be exchanged during the measurement campaign. The researchers have designed a total of three cabin layouts to accommodate different combinations of instruments. There is one variant for each particular question on atmospheric chemistry. Depending on the meteorological and chemical situation in the air layers they fly through, layouts will be changed during the campaign.

SUCCESSFUL DRY RUN

In order for this remodelling to work smoothly under field conditions, in November 2011, Zeppelin technology specialists and Jülich researchers successfully tested all the functions as well as the installation and removal of the scientific instruments under realistic conditions. Dr. Astrid Kiendler-Scharr (IEK-8) explains, "This test run is immensely important and gives us confidence for our work later in the field, for example, when we have to act quickly and remove instruments due to weather conditions or other factors." ::

Jülich climate researchers fill the top platform with instruments. The platform is perched on the top of the airship and collects data on the atmosphere's self-cleansing ability.



Born from dust: At the John von Neumann Institute for Computing, scientists investigate unexplained aspects of planet formation.

Supercomputing for Scientific Purposes

It was a milestone of supercomputing in Germany. In 1987, Deutsches Elektronen-Synchroton DESY, Forschungszentrum Jülich and the Society for Mathematics and Data Processing (GMD) founded what would later become the John von Neumann Institute for Computing (NIC). This was Germany's first supercomputing centre to operate on a national basis that permitted science and industry to efficiently use supercomputers for sophisticated simulations.

With over 65,000 processors stored in 16 racks, JUGENE was the world's fastest civil supercomputer when it was put into operation.

This concept has made Jülich Europe's leading centre for supercomputing. Requests for computing time come from physics, materials research, climate sciences, and medicine. To this end, scientists at NIC constantly refine the required methods and processes – with great success. Kurt Kremer's solid state research that was awarded the 2011 Polymer Physics Prize or the first completely fundamental calculation of the mass of a proton, a component of the atomic nucleus, in 2008, are just two achievements demonstrating this success. Each of the well over 200 projects that are currently under way on Jülich's supercomputers JUGENE and JUROPA are pioneers in their disciplines. We would like to present four of these projects in more detail. They represent the variety of the computations.

Astrophysics

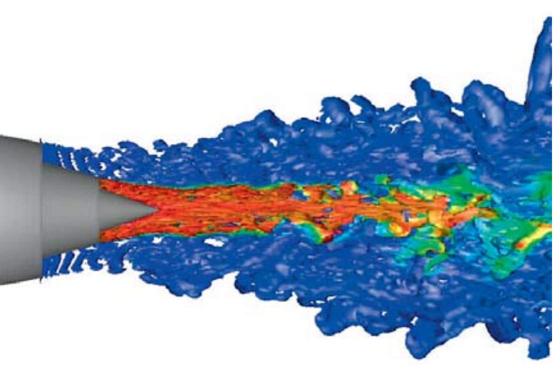
The Formation of Planets

At the beginning of modern science was the experiment. It makes life difficult for the field of astronomy. Stars and planets evolve and disappear over billions of years, with their sheer size making experimental set-ups nearly impossible. Simulation by means of supercomputers provides assistance. “Supercomputers have completely changed our research,” explains Heidelberg astrophysicist Natalie Raettig. The researcher at the Max Planck Institute uses complex simulations on JUGENE to investigate a previously unexplained aspect of planet formation: how are the first metre- to kilometre-sized lumps of stone, referred to as planetesimals, formed through turbulences in dust clouds? The simulation takes into account aspects such as magneto-hydrodynamic processes or gravitation. “With increasing computing power, we can approximate our simulations to emulate the complexity of the real world,” says the scientist, whose research has helped her to take a further step towards solving the riddle of planet formation.

Aeroacoustics

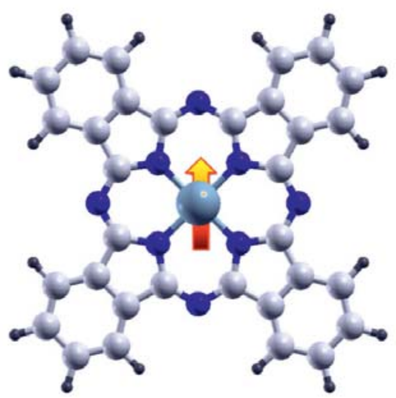
Getting to the Bottom of Aircraft Noise

Legend has it that physics Nobel laureate Werner Heisenberg said that if he met God, he would ask him two questions: “Why relativity? Why turbulence?” It is said that he only expected an answer to the first question. The problem of how acoustic noise is created by turbulence is the focus of the research conducted by Georg Geiser at RWTH Aachen University’s Institute of Aerodynamics. He uses JUGENE to simulate the generation and spread of acoustic noise caused by jet turbines. Turbulent flows, like the free jet that exits aircraft engines, are considered to be one of the most frustrating enigmas of his discipline. They have such a chaotic course that they do not necessarily behave the same even under measurably identical conditions. In order to identify what causes the noise in jet turbines, Geiser requires enormous computer power. “The variables of the fundamental equations interact strongly at various scales. While solving them is extremely complex, it can reveal ways to control it,” the engineer adds. This provides people who live near airports with the hope of more peace and quiet.



Materials Research

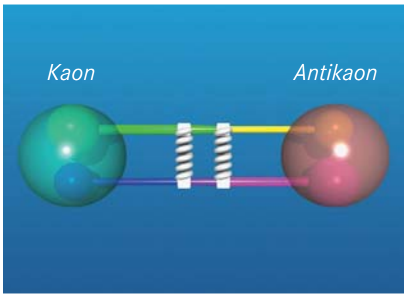
Organic Data Storage Devices



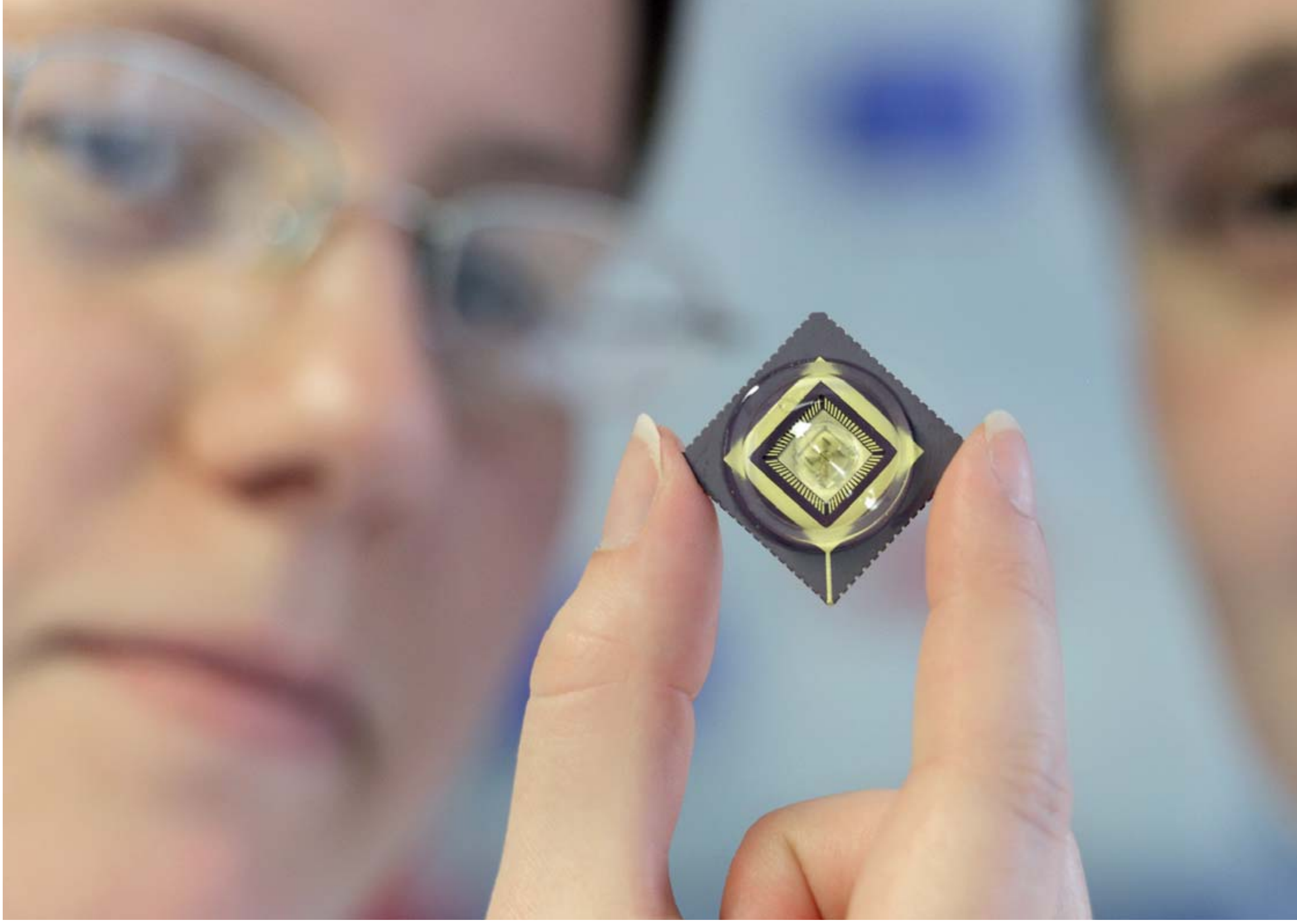
The future of the computer depends on materials. How can you store more and more data on less and less space? As the silicon technology used to date will reach its limits in future, organic materials are increasingly being used for storage. However, the application is still in its infancy. Forschungszentrum Jülich’s Dr. Nicolae Atodiresei is performing basic research that is attracting international attention. He is investigating how the spins of the electrons can be controlled by molecules in order to store data by means of these spintronics. To this end, Atodiresei is simulating the behaviour of pi-conjugated molecules on an iron-tungsten surface. He not only needs JUGENE’s computing power to simulate the behaviour of large groups of atoms, but also to set the theoretical framework for the new field of molecular electronics and spintronics. “I combine elements from physical and chemical theories. This makes things significantly more complex, calling for much higher computing power.”

Elementary Particle Physics

Computing the Excess



What is matter, and why do we exist? The standard model of elementary particle physics explains what holds together the innermost part of the world, what particles it consists of and what forces are at work between them. This makes it a sort of foundation of physics. However, the excess of matter compared to antimatter constitutes an unresolved problem. Without this excess, our existence would be inconceivable. A collaboration of researchers from Budapest, Marseille, and Wuppertal used JUROPA and JUGENE to precisely determine a contribution to this asymmetry. A tiny irregularity during the decomposition of kaons – unstable, short-lived particles – and their antiparticles, the antikaons, was already identified in experiments some time ago. This “indirect CP violation” is an approach that can be used to explain excess matter. The researchers simulated the anomaly on Jülich’s supercomputers just as the standard model had predicted. While this required an enormous computational effort, it confirmed the standard model with unprecedented precision. ::



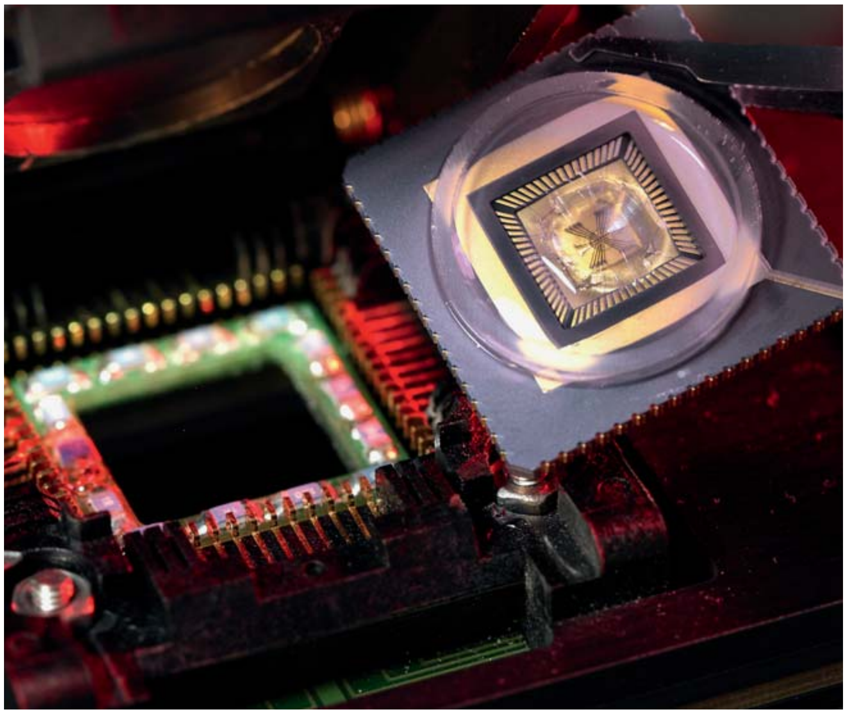
Seeing, Hearing, Moving – Innovative Microchips

The blind see, the lame walk, the deaf hear – novel microchips could make this ancient dream that has been around for millennia come true. Researchers from Munich and Jülich have designed and utilized a biocompatible chip that receives and transmits signals from living cells. In their work, they use a promising material that has only been intensively investigated since 2004: graphene.

Graphene consists of pure carbon that forms a two-dimensional network. With a thickness of only one atomic layer, this honeycomb mesh is inconceivably thin. Nevertheless, graphene is extremely stable. Its tensile strength, for example, is 125 times that of steel. Due to its high electric conductivity, it is considered a possible successor to silicon as a material for transistors. It is also chemically stable and in the experiments carried out so far, it has proven to be particularly biocompatible.

"The reason why graphene is so exciting for us that it can be used to produce flexible and ultrathin mesh or foil – you could put this on the brain, for example, where it could receive and transmit signals from large areas very close to the cells", says Jülich physicist Michael Jansen. What Jansen describes is a pioneering vision, which would for instance give patients who are paralysed from the neck down entirely new options for communication and action.

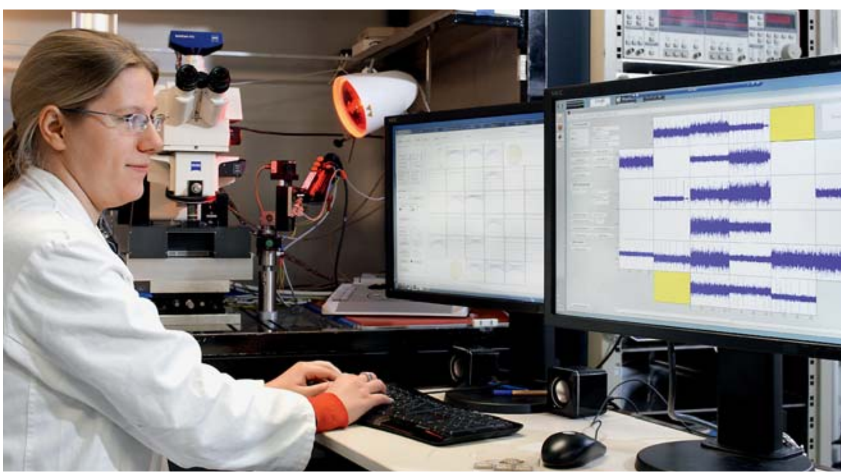
As part of the NeuroCare project, researchers are using electronic components made of graphene to obtain a better connection between neurons and electronics for subsequent use in neuroimplants.



HEALTHY PULSE

Munich scientists developed a microchip made of graphene in order to move this vision an important step closer to reality. Jülich researchers then grew a layer of heart cells on the chip to test whether signals are transmitted by the cells. "We found that the cardiac cells do very well on the graphene chip and that they develop a healthy pulse," says Jülich biologist Dr. Vanessa Maybeck. Using the chip and a measurement set-up developed at Jülich, the researchers electronically observed and recorded the propagation of action potentials that is typical of heart cells. When they added the stress hormone noradrenaline to the nutrient solution, the heart cells reacted with an increased pulse rate. Comparative measurements performed by the colleagues in Munich with silicon-based electronic modules also revealed that the background noise is considerably lower in the graphene transistors.

The researchers confirm that neurons can also be grown on the new material without any difficulty. Scientists at the Vision Institute in Paris are currently testing the biocompatibility of graphene layers with cultures of retinal neurons. These activities are embedded in the broad-based European project NEUROCARE launched on 1 March 2012. Twelve institutes in six countries are working on new concepts for visual, hearing and neural implants. Their aim is to develop more compatible and highly sensitive implants to replace destroyed sensory cells, or to control prostheses. ::



Recording of the propagation of electrical action potentials typical of cardiac muscle cells.

Link tips

→ *www.fz-juelich.de/pgi/pgi-8/*
→ *www.wsi.tum.de/Research/GarridogroupE25/Research/tabid/356/Default.aspx*

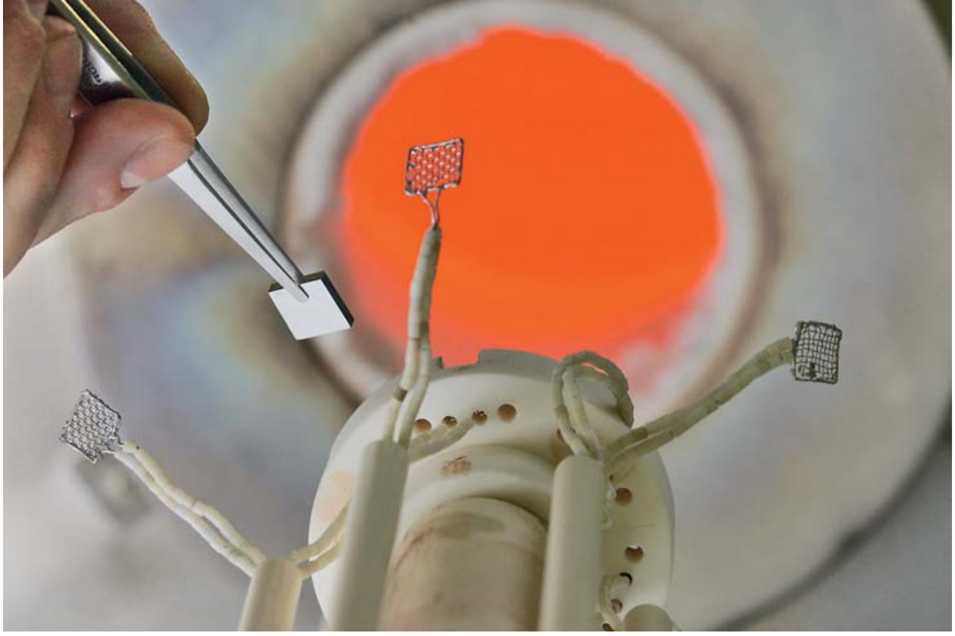
Robust Steel for the Most Exacting Demands

Mechanically stable, highly resistant, and easy to process – a new steel alloy from Jülich gives fresh impetus to the development of fuel cells and energy-saving drives. The rapid market launch of the new steel is the result of close collaboration with industry partner ThyssenKrupp VDM.

The secret of the new material: the addition of small amounts of tungsten, niobium, lanthanum and silicon. This mixture results in a steel that is able to withstand the high temperatures in fuel cells of up to 900 °C. Another advantage of the new material is that when it is heated, the expansion is similar to that of the ceramics used in fuel cells. This means that no mechanical stresses between the two materials damage the ceramics, which could cause the fuel cell to fail.

Prof. Willem J. Quadakkers and his team at Jülich's Institute of Energy and Climate Research have developed this steel alloy on the basis of a precursor. "It was a multistep process," says Prof. Quadakkers. "The first alloy for which we filed a patent in 2000 was still produced in a complex vacuum induction furnace. Now, all that's required for manufacturing the new steel is a conventional melting process." The new alloy is marketed under the trade name Crofer® 22 H and was optimized in cooperation with industry partner ThyssenKrupp VDM. The robust material is now used in high-temperature fuel cells, for example, in the form of "metallic in-

Researchers are analysing the new steel alloy for chemical changes of the surfaces for use in fuel cells (SOFCs).



Testing material at high temperatures: the new steel alloy must demonstrate good electrical conductivity at operating temperatures.

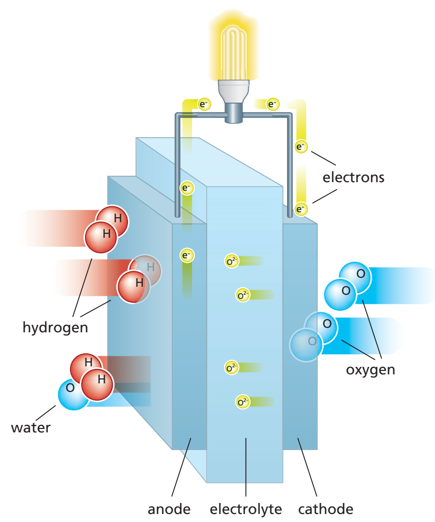
terconnects" – plates that connect several cells to form a more powerful stack. Thanks to the high stability of the new Crofer® 22 H stainless steel, the thickness of these plates can now be reduced, saving an enormous amount of weight and material.

HEAT-RESISTANT EXHAUST SYSTEMS

In the course of the imminent turning point in energy production and rising prices for fossil fuels, the widespread use of fuel cells is unstoppable. Fuel cells will be used in future to power cars, trucks, aircraft and ships, and they are also suitable for stationary applications in buildings as combined heat and power units. The robust steel may also have a future in other fields of application: exhaust systems in cars have to withstand increasingly higher temperatures due to the trend towards smaller engines, and in coal-fired power plants, steam temperatures are also rising, as this increases overall efficiency. The Institute of Energy and Climate Research is currently investigating whether exhaust systems and pipes can be made more heat-resistant based on the know-how acquired during Crofer® 22 H development. ::

Efficient Converters of Chemical Energy

Air is fed into the cell at the positive pole, i.e. the cathode. The oxygen molecules (O_2) in the air take up electrons from the cathode material. As negatively charged ions (O_2-), they migrate through the electrolyte to the anode, i.e. the negative pole, where they react with the hydrogen (H_2) to form water (H_2O). In so doing, surplus electrons remain that are given off to the electrode. This causes the electric circuit to close and an electric current flows between the two poles.



Several planar solid oxide fuel cells (SOFCs) can be combined to make one stack. This stack has a power of 5 kW.

Safety, Synthesis and Spintronics

Thinking outside the box, coming up with creative solutions – that's something that young researchers do particularly well. As heads of the Helmholtz Association's young investigators groups, they have the right conditions for this: an annual budget of at least € 250,000 for five years, the possibility to employ their own staff, and the prospects of a permanent job if their work receives a positive evaluation. This year, three groups are joining the thirteen groups that are already funded in Jülich.

Data Storage Devices of the Future

"We need new approaches," says Dr. Martina Müller, 32, from Jülich's Peter Grünberg Institute, confidently. Computers are expected to process data increasingly faster and more powerfully in future – and, at the same time, use less energy. With these challenges, conventional semiconductor technology is reaching its limits. "In future, in addition to the charge of the electrons, components will also have to use their magnetic properties, the spin," says Müller. "We develop and investigate materials that can do just that." The research area in which the physicist is at home, referred to as spintronics, is still young. The materials she works with are called oxides. The researcher recently succeeded in taking a first step towards developing new components. With her working group, she fabricated a high-purity layer of europium oxide only a few atomic layers thick on silicon, and, in so doing, created a promising link between existing silicon technology and new materials. ::

AT FORSCHUNGSZENTRUM JÜLICH, I ESPECIALLY APPRECIATE ...

... the good mixture of young scientists and "old hands", along with the outstanding infrastructure. Dr. Martina Müller

Original article:

→ *http://onlinelibrary.wiley.com/doi/10.1002/pssr.201105403/abstract*

Solutions for Radioactive Waste

"Making our planet a bit safer" is the declared objective of Dr. Evgeny Alekseev of the Institute of Energy and Climate Research. Alekseev, a 31-year-old chemist, is investigating the scientific principles for final disposal of radioactive waste. His work focuses on the "actinoids", a group of chemical elements that also includes uranium and plutonium. Alekseev concentrates on their solid-state chemistry, i.e. their crystal structure and the unusual chemical and physical properties of compounds with these particularly long-lived radioactive elements. "We would like to know what structures the actinoids assemble into in combination with other materials and how this and external conditions impact on their properties," Alekseev says. "In this way, we can improve models in order to predict how the radioactive substances could behave under the conditions of a final storage facility." He also intends to use this knowledge to specifically develop new materials in which the actinoids are part of the crystal structure and, as a result, are retained especially effectively. ::

AT FORSCHUNGSZENTRUM JÜLICH, I ESPECIALLY APPRECIATE …

… the exciting mixture of brilliant minds from a wide range of disciplines. Dr. Evgeny Alekseev

Soft Synthesis

"For every construction project, you need to have the right tools in your toolbox." This is the way biotechnologist Dr. Dörte Rother, 33, describes her vision. However, she isn't talking about hammers and files. The construction projects pursued by the early-career scientist from the Institute of Bio- and Geosciences are chemical molecules – or, more precisely, building blocks for medications – and her tools are highly specialized proteins. These enzymes are to replace and supplement conventional chemical production runs, such as those used to manufacture medications. In this way, the enzymes from affordable initial substances can also synthesize high-quality building blocks that are very difficult to chemically produce with this degree of purity. Other advantages: synthesis with enzymes produces no hazardous waste and the resources used are renewable. In order to have the right tool on hand for each construction phase, Rother uses naturally and specially modified enzymes. She also develops methods for how these enzymes collaborate, for instance, as cascades connected in series. "Our goal is to obtain a collection of enzymes, an 'enzyme toolbox', from which a number of products can be constructed by means of cleverly combining the enzymes." It's a convincing approach. The first industrial partners have already indicated their interest in enzymatic multistep synthesis. ::

AT FORSCHUNGSZENTRUM JÜLICH, I ESPECIALLY APPRECIATE …

… the possibilities for development offered by Forschungszentrum Jülich. Especially in new projects, or for experiments with unusual methods, there are experts with whom you can search for creative solutions in an interdisciplinary fashion. Dr. Dörte Rother

GLORIA

Unique Experiment for Climate Research

Precise measurements of the atmosphere are indispensable for predicting climate change and its consequences. A research group from the Helmholtz Association centres in Jülich and Karlsruhe therefore started a unique experiment in the northern Swedish city of Kiruna. For the first time, the new GLORIA instrument they jointly developed flew on board the research aircraft Geophysica, observing climate-related gases and atmospheric movements with unprecedented accuracy from an altitude of twenty kilometres. These measurements help to significantly improve climate models.

GLORIA stands for "Gimballed Limb Observer for Radiance Imaging of the Atmosphere". It is a novel infrared camera that separates the thermal radiation emitted by atmospheric gases into spectral colours. This allows these gases and their large-scale movements to be mapped in great detail. GLORIA is the first device worldwide in a new generation of measurement instruments that will also be used on satellites in future, for instance, for weather observation.

At an altitude of ten to twenty kilometres, the device registers numerous climate-relevant trace gases that are mixed here vertically and horizontally. For the first time, this new instrument will measure these processes with a very high spatial resolution, which will allow scientists to test and improve current climate models.

Measurements with GLORIA also focus on the "gravity waves" in the atmosphere – strong air turbulences caused by certain weather conditions, for instance, on the back of mountain ridges. While in aviation, these waves are dreaded, they play an important role for the climate. Gravity waves drive global circulation systems in the middle and upper atmosphere. The dynamics of these waves changes with an increasing carbon dioxide concentration in the Earth's atmosphere. For future climate prognoses, it is very important to understand these effects in detail.

The spectrometer will be on board the new German research aircraft "HALO" starting in summer 2012. And from 2020, plans call for an instrument version suitable for use in space to record major climate data on board an ESA satellite. ::

In continuous contact with the scientists: the Russian pilot of the Geophysica, Oleg Schibitkow.

PUBLICATION DETAILS

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