HEAD IN THE CLOUDS
How Martina Krämer Reads Ice Clouds to Understand Climate Change

Tunnel Versus Mountain Top: How Transistors Save Energy

Early Bird or Night Owl: Brain Mirrors Internal Clock
Chaos in the atmosphere: the region extending to an altitude of 2,000 metres above the ground is characterized by turbulent air movements. The air masses in this planetary boundary layer are always on the move. Factors affecting the air flows include mountains and buildings. If a flow is disturbed too much, then different air masses mix together, causing turbulence (which is most pronounced in the yellow areas). The problem is that turbulence, which changes rapidly, has an impact on the climate, as important exchange processes, for example of heat and water, take place in the planetary boundary layer. Dr. Juan Pedro Mellado from the Max Planck Institute for Meteorology has made the movement of air masses visible using simulations on Jülich’s supercomputers. “Progress in supercomputing has made it possible to study mixing processes in more detail and to learn more about their underlying principles,” says Mellado.
CONTENTS

:: NEWS IN BRIEF

:: COVER STORY

6 Dr. Krämer and the Clouds
Martina Krämer investigates ice clouds and climate change

11 The Cloud Observatory
Instruments on a Jülich rooftop

:: RESEARCH AT THE CENTRE

12 A Booster for the Environment
Cleaning brushes without harmful solvents

14 Stability Brings Change
Self-organization: how our brain deals with damage

16 Green Electronics: No More Mountain Climbing
New transistor reduces energy consumption of electronic devices

18 Stabilizing Factor for Cells
Keratin proteins give skin and tissue their elasticity

20 Night Owl or Lark: How Our Internal Clock Ticks
Nerve fibres in the brain show who’s a late riser

:: LAST BUT NOT LEAST

22 30 Years of TEXTOR
Fusion research decommissions large-scale facility and takes new paths

23 Publication Details
Leibniz Prize for Materials Researcher Prof. Rainer Waser

Peter Grünberg Institute | The German Research Foundation (DFG) awarded a 2014 Gottfried Wilhelm Leibniz Prize to Jülich materials researcher Prof. Rainer Waser. The accolade, which is worth up to € 2.5 million, is considered Germany’s most prestigious research prize. Waser pursues promising approaches for novel electronic components that could drastically reduce the energy consumption of computers, sensors, and energy converters. The scientist, whose background is in physical chemistry, is also a professor at RWTH Aachen University as part of the Jülich Aachen Research Alliance (JARA).

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Recycling of Radicals

Institute of Energy and Climate Research | Hydroxyl (OH) radicals are recycled effectively during the degradation of isoprene in the atmosphere. This has been demonstrated for the first time by Jülich troposphere researchers in experiments using the SAPHIR atmosphere simulation chamber. OH radicals remove pollutants and trace gases from the air. They also decompose isoprene, the most important natural hydrocarbon, which is emitted primarily by forests. During this process, new OH radicals are produced. To date, the scientific community could only speculate about this mechanism. The SAPHIR experiments not only confirmed the mechanism, the scientists were also able to determine how many OH radicals were regenerated. To this end, they recreated the natural conditions prevailing in the atmosphere above China and the tropical rainforests in the simulation chamber.

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:: EDITORIAL

Our climate resembles a huge jigsaw puzzle: we don’t know exactly how the pieces fit together, and some pieces are still missing. Clouds are one of the great unknowns in this puzzle. Researchers at Forschungszentrum Jülich are investigating the formation and composition of these ethereal structures, as well as their impact on the climate. Their findings could be an important step forward for climate simulations.

In this issue, you will also learn how our scientists contribute to conserving our environment and resources – for example by developing energy-efficient transistors and a paint remover without solvents. And if you have always wanted to know why you can never seem to “rise and shine” in the morning: our researchers have some interesting new answers to this question.

I hope that this issue makes for interesting reading!

Yours sincerely,
Prof. Achim Bachem
Chairman of the Board of Directors of Forschungszentrum Jülich

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Forests emit isoprene, which is decomposed in the air by OH radicals.
Malaria Diagnosis on a Smartphone

Peter Grünberg Institute | A new device for testing blood samples quickly and cheaply is currently being developed by Jülich scientists in the research project “LIVECheck”. The device could diagnose infectious diseases such as malaria on the spot – for example in regions that lack medical infrastructure. The necessary information from the blood samples is delivered by nanosensors in the device that are made of conductive inks. The results are transmitted in the form of electronic signals, for example to a smartphone. One of the objectives of the project is to establish an automated manufacturing process for the sensors.

Solar Plasma on Earth for 30 Seconds

Institute of Energy and Climate Research | An international group of scientists including researchers from Jülich has taken another important step on the road to using nuclear fusion as an energy source. Using radio waves, the team confined a high-energy plasma for a record 30 seconds in the Chinese fusion experiment Experimental Advanced Superconducting Tokamak (EAST). Nuclear fusion, which is considered a safe, environmentally friendly, and almost inexhaustible source of energy for the future, is a reaction in which atomic nuclei merge in the plasma state to form a new nucleus. However, controlling the fusion reaction is extremely challenging from a technical point of view. For a continuous supply of energy, the fusion reaction – which is unstable and difficult to control – needs to be sustained over a prolonged period of time. Nuclear fusion power is modelled on the processes that occur inside the sun, where hydrogen nuclei fuse to form helium at high pressure and extremely high temperatures.

Directly to the screen: nanosensors are being developed for analysing blood samples and delivering the results quickly and cheaply – for example to a smartphone.
Dr. Martina Krämer works with instruments that have names such as FISH, HAI (an acronym which means “shark” in German) and NIXE (“mermaid”). One might reasonably conclude that her research has something to do with the sea. In actual fact, she studies a different kind of accumulation of water droplets or frozen water: clouds. They play an important part in climate change.
E veryone has experienced at some time or other the chilling effect of clouds passing before the sun on a summer’s day. The reason is that clouds do not allow all the radiation from the sun to pass through to the surface of the Earth. However, clouds also heat the lower layers of air by trapping heat radiation reflected by the Earth. On balance, the cooling effect outweighs the warming effect in the case of clouds composed of droplets of liquid water.

Ice particles do not reflect radiation in the same manner as droplets, with the result that for an ice cloud, the net effect can be different. Decisive factors are the number and size of ice particles in these clouds and whether they are densely packed or far apart from each other. But what are the properties of ice clouds around the world, and how are these characteristics, which have an impact on the climate, linked to the conditions under which the clouds are formed? This is exactly what Martina Krämer’s team at Jülich’s Institute of Energy and Climate Research – Stratosphere (IEK-7) is investigating by equipping research aircraft with measuring instruments and sending them into the clouds to collect comprehensive data.

These data are a valuable source of information for researchers worldwide, because they enable more accurate simulations of how the global climate will change in the future. The Intergovernmental Panel on Climate Change (IPCC) believes that clouds will mitigate the expected rise in temperature in response to increasing levels of greenhouse gases in the atmosphere. The IPCC has even put a figure on this cooling effect of clouds, but concedes that the reliability of this figure is low, the reason being that the climate simulations on which it is based come to quite different results.

Computer models are struggling to get to grips with the fact that scientists are still trying to fully understand the processes responsible for the formation and properties of clouds, and above all ice clouds. “Clouds are the largest source of uncertainty in the IPCC’s climate change predictions,” says Martina Krämer.

**LARGEST DATA SET WORLDWIDE**

Clouds that consist exclusively of ice particles are referred to as cirrus clouds. They form at air temperatures of between -90 °C and -40 °C. Above the Arctic, cirrus clouds can be found at altitudes of 5 to 12 kilometres; above the tropics, they are located in the altitude region of 9 to 18 kilometres. Even higher up is where the stratosphere begins, a comparatively dry and warm region that is free of clouds. In several international measurement campaigns and a total of eight and a half hours of flights through cirrus clouds, the Jülich researchers and their colleagues from the University of Mainz have compiled the largest set of data worldwide on the number of ice particles contained in these clouds over different regions of the Earth. “A great many researchers immediately got stuck into these data to verify whether their global climate models correctly reflect the number of ice crystals we measured,” says Krämer. It turned out that, in this respect, the models are not yet an accurate representation of reality and therefore need to be improved.

The Jülich researchers headed by Krämer and Dr. Cornelius Schiller, who passed away in 2012, spent even longer measuring the ice content of cirrus clouds than the number of ice particles. Krämer combined these data with others acquired by US researchers during their own measurement campaigns. She then evaluated the resulting huge data set by comparing it with results from the computer model MAID (Model for Aerosol and Ice Dynamics).

MAID, a model originally developed at the Karlsruhe Institute of Technology and refined by the Jülich researchers, simulates the formation and growth of frozen cloud particles in the atmosphere at different temperatures, air pressures, and levels of air pollution. The model describes two different processes: one of them, heterogeneous freezing, refers to

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**Measuring cloud particles**

NIXE-CAPS consists of two parts. The first of them measures particles that are 0.6 to 50 micrometres in size (a micrometre is a thousandth of a millimetre). Here, polarized laser light oriented at a right angle to the stream of air is deflect ed by each individual particle. Detectors measuring the forward scatter determine the intensity of the scattering, thus identifying the particle size. Other detectors measure the polarization of the backscatter, which provides information on the particles’ shape. In this way, it is possible to distinguish between water droplets and solid ice crystals, because water droplets are spherical (round), and ice crystals are usually aspherical, or irregularly shaped.

The second part of NIXE-CAPS measures particles between 15 and 900 micrometres in size. A laser beam hits the cloud particles and produces a shadow of each one, the size and shape of which are then determined by measuring diodes.
the formation of ice around solid particles, such as mineral dust or soot. The other, homogeneous freezing, is the formation of an ice particle through the crystallization of a liquid particle.

FAR-REACHING CONSEQUENCES

The comparison of the measured data with the model calculations suggests that heterogeneous processes are involved in the formation of cirrus clouds. This finding could have far-reaching consequences, because it means that changes in land use or in the emission of particles by industrial plants could have an impact on the formation of cirrus clouds. “Our results contradict the long-standing scientific doctrine that cirrus clouds are almost exclusively the result of homogeneous freezing and that, therefore, man has no impact on them,” says Krämer. She feels that her results are confirmed by recent results from US scientists, who used mass spectrometry to detect desert dust and organic substances in the ice particles of cirrus clouds.

Water or ice
Rain clouds reflect more sunlight than ice clouds, thus allowing less light to reach the Earth’s surface.

Tropics or Arctic
Certain types of clouds are located at different altitudes depending on their geographical position. For example, pure ice clouds – known as cirrus clouds – are located higher up in the atmosphere above the tropics than above the Arctic. One of the reasons for this is stronger upward currents above the tropics. They allow clouds to rise to higher altitudes.
The Jülich team, apart from making measurements and interpreting them, also develops and improves the equipment required for these measurements. This is almost a science of its own: the book on methods and instruments for aircraft-based measurements for environmental research that Martina Krämer co-wrote is more than 600 pages long.

The FISH instrument (Fast In-situ Stratospheric Hygrometer) has been efficiently measuring the ice content of cirrus clouds for many years. The instrument, which was designed by Jülich scientists, has participated in international intercomparisons with similar instruments where it proved once again that the results it delivers are particularly reliable. Another instrument, known as HAI, enables researchers to determine the amount of water contained in clouds and whether this water is present in a gaseous, liquid, or solid state – and all this based on just one measuring principle.

TWO IN ONE
The Jülich scientists named the most recent addition to their range of instruments NIXE-CAPS (New Ice eXpEriment – Cloud and Aerosol Particle Spectrometer). It measures the number and size of cloud particles and determines whether they are liquid or frozen. Strictly speaking, NIXE-CAPS consists of two instruments (see “Measuring cloud particles”), but it only takes up one of the few places available for mounting instruments onto an aircraft. The Jülich cloud researchers were among the first worldwide to use CAPS. They reported any problems they experienced to the manufacturer and gave suggestions for improvements that have now already been incorporated into the latest generation of devices. In addition, they developed a computer library for advanced data analysis.

Krämer’s team has already used NIXE-CAPS to analyse clouds consisting of ice crystals and water droplets in a cloud chamber and in two measurement campaigns. “These mixed-phase clouds occur more frequently than cirrus clouds, in particular above the mid-latitudes, and must also be taken into account in global climate models. However, we still know very little about them,” says Krämer. Her team’s measurements challenge some of the prevailing assumptions made by experts. First, they showed that ice particles can be smaller than 50 micrometres in size. Second, it turned out that round ice particles exist in the atmosphere. And third, they proved that clouds or parts of clouds frequently consist of both liquid water and ice.

Airliners for Research
The researchers headed by Martina Krämer are always eager to collect as many data as possible, because the process of cloud formation is not the same above the tropics as above Europe or the poles, and clouds have different properties at an altitude of 3,000 metres than they do at 11,000 metres. In future, the scientists’ hunt for data will be supported by a research alliance involving 17 European partners, including Lufthansa, British Airways, and Air France. The alliance known as IAGOS (In-service Aircraft for a Global Observing System) was initiated and is coordinated by Jülich’s Institute of Energy and Climate Research – Troposphere (IEK-8). A number of commercial airliners started measuring the levels of water vapour, ozone, and carbon monoxide on scheduled flights as part of the previous project, MOZAIC, back in 1994. Today, four IAGOS airliners also acquire information on water droplets and ice particles in clouds.

The measuring equipment used must be more compact and simpler than that used by Martina Krämer and her team on research aircraft. Despite this, the instruments will have to demonstrate whether their measurements are equally reliable and accurate in a direct comparison during a measurement campaign above the Arctic this year. Martina Krämer says, “If the IAGOS instruments deliver in the test, then they can indeed be used to capture an unprecedented amount of data.”

Dr. Frank Frick
Investigating clouds doesn’t necessarily involve flying through them with aircraft and measuring instruments. While it’s true that these in situ measurements, as experts call them, deliver particularly accurate and detailed information, satellites also produce valuable data, for example on global cloud cover and on the properties of clouds distributed over large areas. There is also a third option: scientists can use remote sensing instruments to observe the clouds from the ground.

This is precisely the purpose of the new cloud observatory JOYCE (Jülich Observatory for Cloud Evolution). Almost all of its instruments have been installed on the roof of the Institute of Energy and Climate Research – Troposphere (IEK-8). One of them is the MIRA cloud radar, which can send microwave pulses in any direction in space. The backscattered radiation provides the scientists with data on the thickness and structure of clouds. Another JOYCE instrument is AERI, the Atmospheric Emitted Radiance Interferometer. Using infrared radiation, it reveals the size of cloud droplets and other properties.

With JOYCE, scientists from the universities of Cologne, Bonn, and Aachen and researchers from Forschungszentrum Jülich are investigating processes of cloud formation and cloud development over longer periods of time. “We’re particularly focusing on cumulus clouds and other precipitation-bearing low-level clouds located just above the planetary boundary layer at an altitude of about 1,500 metres,” says Jülich researcher Dr. Birger Bohn.

Dr. Frank Frick
In Germany alone, a million litres of paint brush cleaner are used for DIY purposes every year. Most of these cleaners are based on solvents that are harmful to our health and the environment – indicated by the orange and black hazardous substance symbols on the label and the pungent smell. “If it doesn’t stink, it doesn’t work,” is how Dr. Jürgen Allgaier summarizes the belief of many a DIY enthusiast. “Our general-purpose paint remover, which has been available at many DIY stores in Germany since last summer, is evidence that solvents aren’t necessary and that an environmentally friendly product can do the job,” says the chemist from the Jülich Centre for Neutron Science – Neutron Scattering (JCNS-1). The company contributed its expertise as a development partner. For years its engineers tested new formulas on different paints together with the Jülich scientists and dealt with legal matters, such as labelling requirements.

FREE OF SOLVENTS

The company’s goal was to provide a solvent-free paint remover for large companies such as road maintenance depots, industrial cleaning companies, printing shops, and packaging manufacturers. The resulting product has recently been put on the market under the brand name of SCHWEGO® clean ME. But what exactly does the cleaner contain? “The exact formula is a secret,” says Dr. Jens Hillerich, chemist at Schwegmann. He won’t give away more than “water, oil, and surfactants”.

Jürgen Allgaier is a little less enigmatic. He says, “One of the greatest difficulties was developing a product that is hazard-free.” Almost all surfactants are hazardous substances and therefore subject to strict labelling requirements. “Eventually, it was the boosting effect that helped us to considerably reduce the proportion of surfactants needed. We also used surfactants that have a low hazard potential. This enabled us to come up with a hazard-free formula,” he explains. What he calls the “boosting effect” is what sets the cleaner apart from other surfactant-based cleaners.

About ten years ago, the Jülich scientists had a different phenomenon in mind: the micelle formation of long-chain polymers. “Similar to surfactants, our polymers consist of a hydrophobic or ‘water-repelling’ hydrocarbon chain and a hydrophilic or ‘water-loving’ one,” says Jürgen Allgaier. “Such polymers are much longer and larger than surfactants. In water, they form structures of various shapes, including spherical.
The cleaner co-developed by Dr. Jürgen Allgaier removes oil and grease with the help of surfactants.

Dr. Thomas Sottmann, two specialists in surfactants at the University of Cologne, they put their idea to the test. At first, they were unsuccessful: the polymers didn’t have the necessary “emulsifying capacity”, as the experts say.

But when they tested a mixture of surfactants and the new polymer, the researchers were in for a surprise. The efficiency of the surfactants – which means their ability to mix a certain amount of oil with water – was greatly increased when a small amount of the polymer was added.

THE INTERFACE IS THE KEY

The polymer they used, however, turned out to be too expensive and not readily biodegradable. But the research activities at Jülich drew the attention of the Schwegmann company, and more than six years ago, they started the first joint experiments. About two years ago, Alfred Clouth Lackfabrik, a company from Offenbach, also expressed an interest in developing and bringing to the market an environmentally friendly paint remover for DIY enthusiasts.

The breakthrough eventually came from the researchers’ detailed understanding of how the polymer affects the interface between oil, water, and surfactant. With the help of neutron scattering experiments, they discovered that in the mixture of water, surfactant, and oil, the polymer displaces some of the surfactant molecules. It becomes part of the surfactant film surrounding the droplets of oil. Its long chains are then tangled up on both sides of the film, and the resulting molecular forces stiffen the interface between water and oil. As a consequence, larger droplets of oil are formed, the total surface area of which is smaller than if the same volume were distributed over many smaller spheres. This means that less surfactant is required to cover the surface of the large droplets.

The next step was to find a molecule with similar properties that was cheaper and biodegradable. “It is a triumph of the cooperation between physicists and chemists, theoreticians and experimenters that we found a booster meeting these requirements,” says Allgaier. “The molecule isn’t as long – its water-repellent part is much shorter – but it still works,” he is happy to report.

Above all, however, it’s the customers who are satisfied with the product. The microemulsion dissolves water- and solvent-based paint, varnish, glaze, oil, wax, grease, and soot. It removes paint splatters, bitumen, tar, and most adhesives, and is suitable for cleaning spray guns, painting equipment, and mixing units. At the same time, it leaves brushes, fabrics, and surfaces undamaged. One of the positive side effects of the oil contained in the cleaner is that it keeps delicate artists’ brushes with natural bristles supple. Employees at Alfred Clouth Lackfabrik have also tested the new product. Laura Blaschke from the marketing department has a story to tell of a colleague of hers who produces tomato sauce in her spare time. “She soaked her white T-shirt splattered with countless tomato stains in the paint remover for a week – and it came out immaculate.” Smiling, she adds, “Of course, that’s not what the product is intended for. The CLOU® general-purpose paint remover is really only for removing fresh or dried paint from tools used for all kinds of painting jobs.”

Brigitte Stahl-Busse
The brain is permanently under construction – new connections are constantly being formed between neurons, while others are undone. This flexibility is what makes long-term learning possible. Jülich researchers have demonstrated the underlying principles with a network of simulated neurons.

When memories are stored long-term, new contact points (synapses) are formed between the neurons in the brain. Larger-scale reorganization work and repairs can also take place: if a region of the brain is damaged, other regions can often take on the tasks of the destroyed cells. Paradoxically, one of the foundations for this adaptability is the neurons’ pursuit of stability. This is the conclusion that neuroinformatician Dr. Markus Butz-Ostendorf drew from a computer model he used to simulate a region of the cerebral cortex.

Butz-Ostendorf conducts research in the Simulation Laboratory Neuroscience at the Jülich Supercomputing Centre (JSC). Together with his colleague Arjen van Ooyen from VU University Amsterdam, he has presented a new theory explaining the plasticity of the brain in the specialist journal *PLOS Computational Biology.*

For their simulations on the JUQUEEN supercomputer, the researchers are focusing on the visual cortex – a part of the cerebral cortex that processes signals from the eyes. This region of the brain is designed in such a way that the patterns produced on the retina are effectively “projected” onto the cerebral cortex: when two adjacent cells are stimulated in the retina, these also stimulate adjacent cells in the visual cortex.

**CELLS HELP EACH OTHER**

It is thus possible to monitor exactly what happens in the visual cortex when certain brain cells no longer receive any input from the eyes, for instance due to retinal damage. Although animal testing has shown us which rearrangement processes result from such damage, it was previously unclear what controls the formation and elimination of synapses. Butz-Ostendorf and van Ooyen have now succeeded in developing a theoretical model that explains the reorganization of synapses.

The researchers discovered that the brain cells’ efforts to maintain their normal level of electrical activity play a decisive part in the formation of new connections. If hardly any electrical impulses reach a given region, the cells there will soon establish new contacts with their neighbours in order to obtain additional stimuli. To do so, the neurons form new branches off their axons – long extensions that send electrical signals from one cell to another – and off their dendrites, shorter projections that receive these signals. At the point where these branches meet, synapses are created – and thus links between the cells that allow them to receive more electrical signals again.

“The cells help each other. Those with intact input form an increased number of synapses to cells no longer receiving exter-
nal input”, says Butz-Ostendorf. Once the normal level of electrical activity has been regained, the rearrangement work ceases. If there is too much electrical activity, synapses are eliminated. This creates a balance that scientists call homeostasis. These rearrangement processes thus follow different rules than learning processes, which merely strengthen or weaken existing synapses. Psychologist Donald Hebb discovered a simple law for this as early as 1949: frequently used connections become stronger, while those that are seldom used become weaker. “Due to the complex synaptic circuitry in the human brain, it’s not plausible that its fault tolerance and flexibility are achieved based on static connection rules. Models are therefore required for a self-organization process,” says Prof. Markus Diesmann from Jülich’s Institute of Neuroscience and Medicine (INM), who is involved in the project.

The findings obtained using the supercomputer may also be significant for medical science. “In people with partially damaged retinas, new connections are formed in the visual cortex when the cells are stimulated electrically,” says Butz-Ostendorf. “Until now, it had been assumed that the more stimulation received, the better. But we now know that it comes down to providing the right amount at the right time.”

LIKE A HEALING WOUND
The researchers drew this conclusion from their simulations: “With our model, we simulated the same kind of retinal damage that had been investigated in animal experiments,” explains Butz-Ostendorf. “When we adjusted the model in such a way that the dendrites of damaged neurons grew at low levels of cellular electrical activity and axons only at higher levels, the damaged network of neurons formed new connections from the edge of the network inwards, similar to a wound that is healing. This corresponds to the process observed in animal experiments.” He concludes that, for this reason, it is highly likely that the neurons’ rewiring does in fact function according to these principles.

Butz-Ostendorf is confident that in only a few years, it will be possible to measure the electrical activity of neurons using imaging techniques and to adapt medical treatment accordingly. To achieve this, the Jülich researcher is cooperating with doctors from the Institute of Medical Psychology at University Hospital Magdeburg. Looking further ahead, he hopes that the findings could help to specifically promote reorganization processes in the brains of stroke patients.

Dr. Wiebke Rögener
Every IT device contains inverters, which are circuits consisting of two transistors. These inverters convert electronic signals and form the basic units of processors. Essentially, they are simple, everyday components. Yet the inverter that the group headed by Prof. Siegfried Mantl from Jülich’s Peter Grünberg Institute presented at IEDM, the leading electronics conference in Washington D.C., caught the experts’ attention. Why? Because it ensures that certain applications only consume a tenth of the energy they currently do.

The new type of transistor used in the inverter is the first result achieved in the UltraLowPow project supported by the Federal Ministry of Education and Research (BMBF) and coordinated by Mantl. It is the world’s first efficient tunnelling field effect transistor (TFET) based on silicon. This makes it a prototype for a new generation of energy-efficient components.

UNRIVALED EFFICIENCY
“Information technology already consumes enormous amounts of electricity today,” says Mantl, “and it will continue to penetrate into more and more spheres of our daily lives. Apart from computers and smartphones, small smart devices such as sensors that monitor bodily functions will be a major part of everyday life in future. For this reason, there is huge demand for energy-efficient components.” “Components” means, above all, transistors. Because these switches process the units of information “one” or “zero” form the basis of information technology. Even a small decrease in their energy consumption means saving large quantities of energy on a global scale.

The most common type of transistor currently in use is the metal-oxide-semiconductor field-effect transistor, or MOSFET for short. Any attempt to reduce its consumption, however, is hampered by a physical limit. “The decisive factor for energy consumption is the operating voltage. Although MOSFETs perform efficiently at high voltages, they are much less efficient at low voltages,” says Mantl. As a result, MOSFETs are best suited from an operating voltage of 0.6 volts, and in notebooks only from 0.9–1.1 volts and upwards.

This is not the case for the TFET used in the inverter developed by Mantl and his partners from Aachen, Udine in Italy, and Zurich. It switches from as little as 0.2 volts – a world-class performance in terms of economy. The physicist believes that values of 0.15 volts and under are possible. Even at 0.2 volts, however, energy consumption is reduced substantially – to a tenth.

For now, TFETs are not suitable for high-performance applications such as processors. “However, they could replace individual circuits in laptops or smartphones. They are ideal for small devices that don’t require an external power source but produce energy themselves, from body heat or sunlight, for example.”
THROUGH NOT OVER THE MOUNTAIN
What makes the tunnelling field effect transistor so economical? Mantl explains it using a metaphor. “Electrons have to overcome a barrier in a transistor so that it will switch. Think of it as an exhausting climb over a mountain. But since the electrons are quantum particles, they can take a short cut: they can tunnel through the mountain, and only need a low voltage to do so.”

Tunnelling means that a quantum particle can surmount the barrier despite the fact that, according to the laws of classical physics, there is insufficient energy. Causing the electron to achieve this tunnelling effect in a transistor made of silicon, however, is challenging from a technical point of view.

One challenge is producing the transistor. Most of these components are made from silicon, which is mixed with a minute amount of other elements, such as phosphorus or arsenic, to make it conduct electricity. The silicon wafers are bombarded with these high-energy impurity atoms. As this process disturbs the crystal structure, the atoms are returned to their places afterwards by heating the wafers to around 1,000 °C.

TFETs cannot be produced in this way, as the heat treatment scatters the impurity atoms. Although the defects thus created are only a few atomic layers in size, this is sufficient to prevent the jump through the tunnel. Mantl and his team have therefore developed a gentler procedure. “We apply a five-nanometre layer made of a silicon-metal alloy to the silicon and implant the charged particles into this layer. We then drive them into the silicon at a temperature of only 600 °C.”

Another innovation is the use of special nanowires instead of the conventional three-dimensional components. Due to a physical effect, these wires increase the likelihood that the electrons will tunnel. This increases the transistor current.

The researchers initially simulated the construction of the transistor on a computer. They are now constructing the next generation of TFETs and exploring possible applications in Forschungszentrum Jülich’s new cleanroom facility, the Helmholtz Nanoelectronic Facility (HNF). As they are already collaborating with companies, it may not be long until TFETs can be used in industrial applications.

Christoph Mann

Exhausting, isn’t it? In the universe of quantum particles, there is a short cut “through” the mountain – the tunnelling effect. Electrons use this path in a new transistor, thus saving energy.
Skin and gland tissue owe their firmness and elasticity to a special group of proteins known as keratins. Researchers from Jülich, Leipzig, and Aachen have now confirmed this long-standing assumption for the first time. The new findings could help to explain genetic skin diseases.

**Add more bounce to your hair – with keratin in your shampoo.**

Many people are familiar with keratin from adverts for haircare products. This structural protein is considered vital for stability and firmness. Scientists assume that it stabilizes cells. This effect is also important for the body’s external layer – in other words, the skin. If the skin had no elasticity, many undesirable substances would be able to penetrate it and enter the body. The question of what really makes cells stable and protects them from mechanical stress is a central issue in cell biology today. “Any biology textbook will attribute this to keratin – always adding, however, that this is merely an assumption. Until now, we had very few empirical data and no conclusive proof,” says Prof. Rudolf Merkel from the Institute of Complex Systems at Forschungszentrum Jülich. It was previously considered difficult to prove, as keratin is not a single protein, but an entire protein family. Together, scientists from Jülich, Aachen, and Leipzig succeeded in solving the problem. To do so, they isolated and analysed genetically modified epidermal cells – known as keratinocytes – from mouse embryos. These are the cells that produce keratin.

**KERATINOCYTES WITHOUT KERATIN**

The basis for the studies was provided by the team headed by Prof. Thomas Magin from the Translational Centre for Regenerative Medicine and the Institute of Biology at Leipzig University. They genetically modified keratinocytes from mouse embryos in such a way that they did not contain keratins. Normally, these structural proteins account for up to two thirds of the protein mass of keratinocytes. The Jülich cellular biomechanics experts were responsible for determining the stiffness of the modified cells. They did so by examining individual cells under an atomic force microscope. A soft feather was used to indent the cells to a given depth. The researchers measured the force required to do so each time. The result: for the modified keratinocytes, 30% to 40% less force was needed to achieve the same results as for unmodified cells. “This tells us that the cell is much softer and has much less resistance to mechanical stress,” explains Jülich researcher Dr. Bernd Hoffmann, who played a leading role in the study along with Prof. Merkel. What surprised the scientists was that the differences were observed not only in cell clusters, but also at the level of individual cells. Clearly, keratins take effect even before cell layers form.

In addition, further studies conducted by Prof. Rudolf Leube’s research group at the Institute of Molecular and Cellular Anatomy at RWTH Aachen University showed that the internal stability of the genetically modified cells is considerably lower. The researchers inserted small magnetic beads into the cells and then used an electromagnet to move them. In unmodified keratinocytes, the beads slid back to their original position when the magnet was turned off. In the modified keratinocytes, the beads remained where the magnet had pulled them, and eventually were torn from the cell completely.

**EXPLANATION FOR SKIN DISEASES**

The groups’ findings represent a major step forward for research. A number of human diseases are linked to the protein...
group of keratins and are probably caused by the lower mechanical stability of cells. The researchers’ success in demonstrating the function of keratins could help to provide an explanation.

One example is the inherited skin disease epidermolysis bullosa, also known as the butterfly disease. A congenital mutation in certain genes causes blisters and sores on and inside the entire body from infancy. The disease can lead to severe disability or even to premature death.

Keratins are not only important in the skin, but in all barrier layers in body tissue – for example, in external layers of gland tissue, such as in the pancreas. The external layers protect the internal gland cells, which are very soft. These layers are occasionally exposed to forceful mechanical stresses, for instance from movements or shocks. Having focused solely on individual cells thus far, the researchers will now investigate larger sections of tissue. They want to find out what additional or reinforcing effects keratins have on the mechanics of tissue.

Christian Hohlfeld
Night Owl or Lark: How Our Internal Clock Ticks

Whether still partying in full swing in the early hours of the morning or leaping out of bed as fresh as a daisy: 10–20% of people are either avowed night owls or like to be up with the lark. A study by Jülich researchers has shown for the first time that this is linked to physiological differences in certain areas of the brain.

Each of us has an internal clock that determines when we feel the need to sleep or to get up, explains Dr. Jessica Rosenberg from the Institute of Neuroscience and Medicine at Jülich. How this clock ticks depends, among other factors, on our genes. People who get up extremely early or go to bed extremely late – known to experts as early and late chronotypes – are relatively rare. Most people’s biorhythm is somewhere in the middle. Until now it had been unclear whether extreme chronotypes differ from others in physiological terms. Jessica Rosenberg and her team have now demonstrated that people who are very active at night display different signal transduction in the nerve fibres in certain areas of the brain.

FOCUS ON WHITE BRAIN SUBSTANCE

Using a special magnetic resonance imaging technique (diffusion tensor imaging, or DTI), the researchers measured signal transduction in the white brain substance of early, normal, and late chronotypes. Some background information: the white brain substance mainly consists of nerve fibres, which are responsible for transporting information in the brain. The researchers then compared the data thus obtained with images of the test subjects’ brains. “It was found that in the brains of people who are very active at night and can only go to sleep in the early hours of the morning, signal transduction is different, for example in the brain regions below the frontal and temporal lobes or in the anterior cingulate gyrus,” explains Jessica Rosenberg. These regions of the brain are active during learning, speaking, or remembering, for example. Future re-
search projects will show whether the differences determined are the cause or the consequence of this extreme nocturnal activity. “Our work is just beginning,” says Jessica Rosenberg.

IN TOP FORM
At present, the team headed by Rosenberg, who also works at University Hospital Aachen’s Department of Neurology as part of the Jülich Aachen Research Alliance (JARA), is working on a further study. This will show whether extreme chronotypes actually do function most efficiently during the times when they feel at their best – that is to say, in the morning or at night. Until now, there have only been behavioural studies in this area.

The Jülich researchers, on the other hand, put early birds and night owls to work in a functional magnetic resonance imaging (fMRI) scanner. They were required to perform attention tests and answer questions on language processing at different times of day. While they completed these tasks, the scientists monitored their brain activity. “The evaluation is still under way, but we are fairly certain that we will find differences in brain activity,” says Jessica Rosenberg.

Even though our own personal sleep–wake rhythm can change over the different phases of our lives, from infancy to puberty to old age, the scientist says that our biological clock can only be altered to a limited extent. “Someone who is an extreme night owl shouldn’t become a baker – they should be a bartender instead,” says Jessica Rosenberg, summing it up. Because if working hours conflict too drastically with a person’s individual need for sleep, the body reacts by feeling stressed. “The permanent lack of sleep experienced by a late chronotype can be compared to chronic jet lag,” says the scientist. This stress may also explain why people who prefer to stay up late into the night often tend to turn more frequently to alcohol and cigarettes than early risers or people with a normal day–night rhythm.

SLEEPING IN CAN HELP
The working world doesn’t just need bakers and bartenders, however. The majority of extreme chronotypes have to adjust to normal working hours – even though they may find this very difficult. Experts recommend that people whose sleep rhythm is out of sync with their working hours should sleep longer on their days off. And in extreme cases, professional light therapy may make it easier for real night owls to get out of bed in the morning.

Ilse Trautwein

Dr. Jessica Rosenberg: “Our individual sleep–wake rhythm can only be altered to a limited extent.”
December 2014: Thirty years of research came to an end with the decommissioning of the large-scale device TEXTOR. Scientists from all over the world produced outstanding results and made major contributions towards understanding fusion in numerous experiments at the facility. The challenge that now remains is to construct a fusion reactor. This involves ensuring steady-state operation and developing suitable materials. These are basic requirements for an environmentally friendly and safe power plant that will generate energy according to the principle of the sun’s fire.
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