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RESEARCH NEWS

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1 Power grid of the future saves energy

Green energy too comes out of the electricity socket, but to get there it has to travel a long journey – from wind turbines in the North Sea or regional solar, wind and biogas power plants. On the way to the consumer lots of energy is lost. New electronic components will change things in future.

2 Dressing indicates infections

Wounds have to be regularly checked, to make sure any complications in the healing process are detected at an early stage. A new material will make it possible to check wounds without changing the dressing: If an infection arises, the material changes its color.

3 Perfectly needled nonwoven

Hardly any other textile is as versatile as nonwoven: it keeps babies' bottoms dry and protects plants from the sun. In the Gulf of Mexico, special nonwovens soaked up the oil washed up on beaches like blotting paper. A new piece of simulation software now makes it possible to produce high-quality, stripe-free nonwoven fabrics.

4 Underwater robots on course to the deep sea

Robots do not have to breathe. For this reason they can dive longer than any human. Equipped with the necessary sensor technology they inspect docks or venture down to the ocean floor to search for raw materials. At present, researchers are developing a model which will carry out routine tasks independently, without help from humans.

5 Conductor paths for marvelous light

Organic light-emitting diodes are seen as the basis for a new generation of lamps: Large-area lamps that can be randomly shaped and flexibly integrated into interior design. But the "illuminated glass" is still very expensive. Researchers want to optimize the lamps of the future and reduce the price by a new manufacturing process.

6 On the way to lead-free technology

The change-over to lead-free products is in full progress. The problem is however that the environmentally friendly alternatives have to be as efficient as the lead-containing variants. One example is the injection system of diesel engines. Lead-free functional materials can be found faster by means of computer simulation methods.

The Fraunhofer-Gesellschaft is the leading organization for applied research in Europe. Its research activities are conducted by 59 Fraunhofer Institutes at over 40 different locations throughout Germany. The Fraunhofer-Gesellschaft employs a staff of around 17,000, who work with an annual research budget totaling 1.5 billion euros. Roughly two thirds of this sum is generated through contract research on behalf of industry and publicly funded research projects. Branches in the USA and Asia serve to promote international cooperation.

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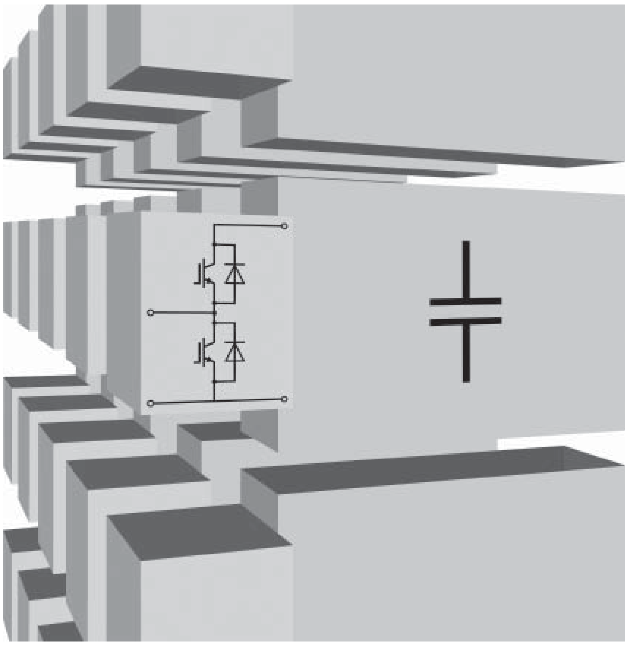
Power grid of the future saves energy

Cars and trucks race down the highway, turn off into town, wait at traffic lights and move slowly through side streets. Electricity flows in a similar way – from the power plant via high voltage lines to transformer substations. The flow is controlled as if by traffic lights. Cables then take the electricity into the city centre. Numerous switching points reduce the voltage, so that equipment can tap into the electricity at low voltage. Thanks to this highly complex infrastructure, the electricity customer can use all kinds of electrical devices just by switching them on. "A reliable power supply is the key to all this, and major changes will take place in the coming years to safeguard this reliability. The transport and power networks will grow together more strongly as a result of electromobility, because electric vehicles will not only tank up on electricity but will also make their batteries available to the power grid as storage devices. Renewable energy sources will become available on a wider scale, with individual households also contributing electricity they have generated," says Professor Lothar Frey, Director of the Fraunhofer Institute for Integrated Systems and Device Technology IISB in Erlangen. In major projects such as Desertec, solar thermal power plants in sun-rich regions of North Africa and the Middle East will in the future produce electricity for Europe. The energy will then flow to the consumer via long high-voltage power lines or undersea cables. The existing cables, systems and components need to be adapted to the future energy mix now, so that the electricity will get to the consumer as reliably and with as few losses as possible. The power electronics experts at the IISB are working on technological solutions, and are developing components for the efficient conversion of electrical energy.

For energy transmission over distances of more than 500 kilometers or for undersea cables direct current is being increasingly used. This possesses a constant voltage and only loses up to seven percent of its energy over long distances. By comparison, the loss rate for alternating current can reach 40 percent. Additional converter stations are, however, required to convert the high voltage of the direct current into the alternating current needed by the consumer.

"In cooperation with Siemens Energy we are developing high-power switches. These are necessary for transmitting the direct voltage in the power grid and are crucial for projects like Desertec. The switches have to be more reliable, more scaleable and more versatile than previous solutions in order to meet the requirements of future energy supply networks," says Dipl.-Ing. Markus Billmann from the IISB. To this end, the research scientists are using low-cost semiconductor cells which with previous switching techniques could not be used for high-voltage direct-current transmission (HVDCT). “At each end of a HVDCT system there is a converter station,” explains the research scientist. “For the converters we use interruptible devices which can be operated at higher switching frequencies, resulting in smaller systems that are easier to control.” A major challenge is to protect the cells from damage. Each converter station will contain about 5,000 modules, connected in series, and if more than a few of them failed at the same time and affected their neighboring modules a chain reaction could be triggered which would destroy the entire station. “We have now solved this problem. With our cooperation partners we are working on tailor-made materials and components so that in future the equipment will need less energy,” says Billmann.



Schematic: The explosion-protected converter cell in the cell network.
Explosion protection reduces the risk of a chain reaction in the event of
a fault, which could cause the entire converter station to fail. (© Fraunhofer IISB)

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Research News
11-2010 I Topic 2

Dressing indicates infections

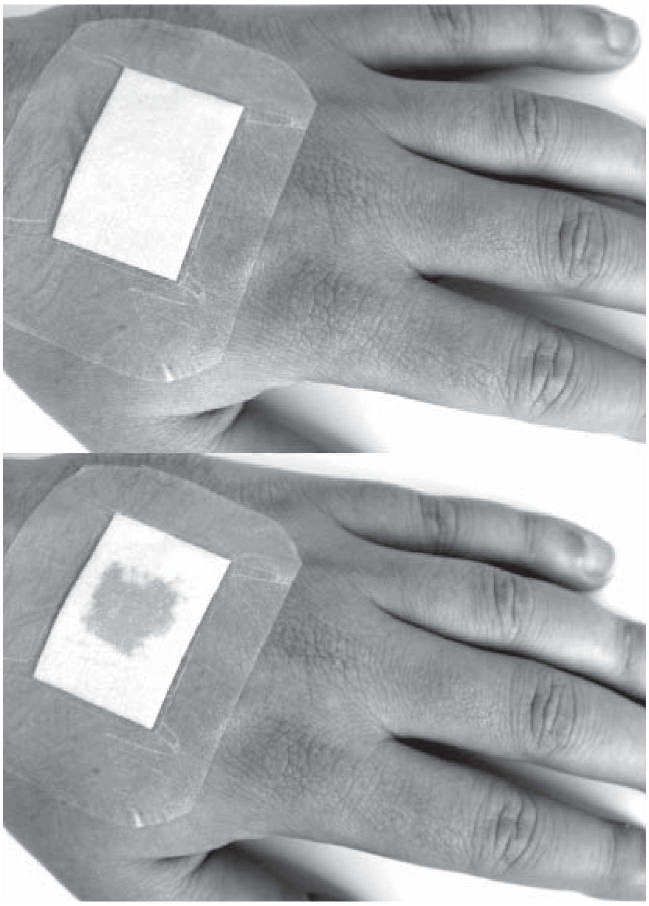
Whether a small cut with a fruit knife, a surgical wound or a major injury caused by a fall – the body's defense and repair system leaps into action and tries to close the wound as quickly as possible. Small injuries usually heal within a few days, but a gaping wound will take longer to heal, and an infection can take hold even after several days. Dressings protect the site of the injury but to check the wound they have to be removed. This can be painful for the patient and moreover it risks giving germs the chance to enter and cause infection. Scientists at the Fraunhofer Research Institution for Modular Solid State Technologies EMFT in Munich have developed dressing materials and plasters which indicate pathological changes in the skin. If an infection is present, the color of the dressing changes from yellow to purple.

"We have developed an indicator dye which reacts to different pH values, and we have integrated it into a dressing and a plaster. Healthy skin and healed wounds usually show a pH value of below 5. If this value increases, it is shifting from the acid to the alkaline range, which indicates complications in the healing of the wound. If the pH value is between 6.5 und 8.5 an infection is frequently present and the indicator color strip turns purple," states Dr. Sabine Trupp, scientist at the EMFT, explaining the chemical reaction. In this way the intelligent dressing material makes it possible to regularly check wounds from the outside without disrupting the healing process.

Production of the color control strip posed a number of challenges for the research scientists as it had to meet several different requirements: "The dye has to remain chemically stable when bonded to the fibers of the dressing material or the plaster to ensure that it does not get into the wound. At the same time, the indicator must show a clear change in color and also react sensitively in the right pH range," says Trupp. The experts succeeded in meeting all these requirements. A prototype of the dressing has already been produced and initial tests have proved successful. The researchers are now thinking about how to develop their innovation further. There are plans to integrate optical sensor modules into the dressing to measure the pH value and indicate the results on a reader unit. This method would allow the value to be read off precisely, providing information about how the wound is healing.

How do we go from here? The next step will be to use the dressing in a hospital environment at the University of Regensburg's dermatology clinic. Dr. med. Philipp Babilas will be medical supervisor to the project: "Our studies of the pH value in acute as well as in chronic wounds have shown that it plays a key role in wound healing."

At present Dr. Trupp and her team are looking for an industrial partner to produce the dressing commercially.



If the wound has become infected the innovative dressing material indicates this by changing color: the yellow plaster turns purple (bottom picture). (© Fraunhofer EMFT)

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Perfectly needled nonwoven

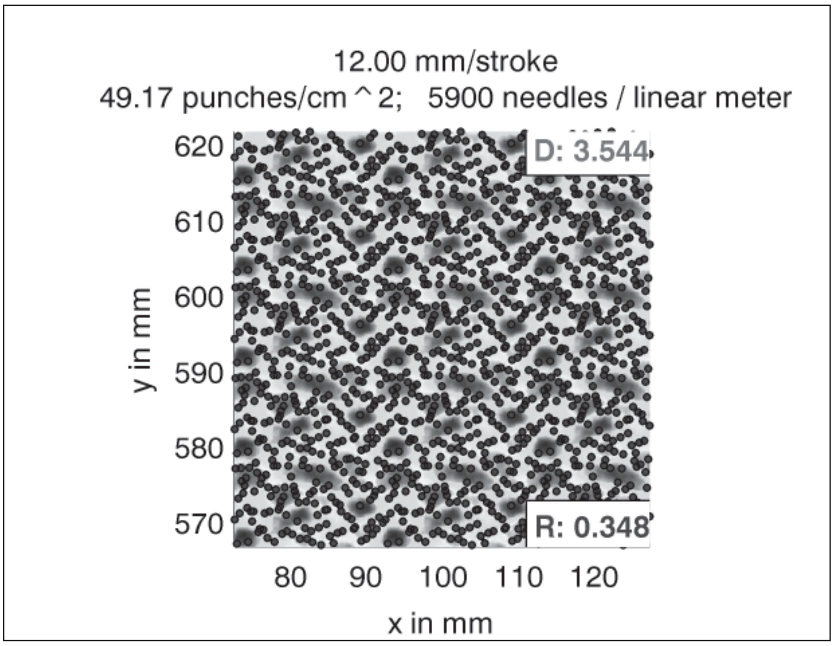
Research News
11-2010 I Topic 3

What do diapers, wiping cloths, wall paneling, sticking plasters and Ultrasuede covers for upholstered furniture have in common? All these products are made of nonwovens. There is hardly any other fabric that is as versatile. Last summer the operators of the Zugspitze railroad even used sheets of nonwovens to prevent the snow melting away on Germany's highest mountain. The quality of this textile, however, varies considerably. It is generally true to say that the firmer, the smoother and the freer of marks the nonwoven is, the higher the quality. In the search for the perfect nonwoven, the Austrian needling machine manufacturer Oerlikon Neumag Austria asked the Fraunhofer Institute for Industrial Mathematics ITWM in Kaiserslautern for help.

Needling machines are essential in the production of nonwoven fabrics: "Nonwovens are bonded mechanically by needling. The needles punch vertically in and out of the material. The machine then transports the material and the needles come down again. This process locks the fibers together," explains Dr. Simone Gramsch, a scientist at the ITWM. "The needle penetrations have to be completely even, otherwise unwanted marks such as longitudinal, diagonal or transverse stripes occur, and the material is less tear-resistant," says Gramsch. Oerlikon Neumag Austria used to conduct the needling process without computer simulations. The needles were arranged manually based on past experience, and the needle boards constructed and tested by trial and error an approach that took several months and cost a lot of money. The research scientist and her team have managed to cut the time needed for this process significantly. There will no longer be a need for practical tests: Using software tools they themselves developed, the scientists have been able to simulate the needle penetration geometry, allowing them to optimize the needle patterns.

The strength and stretch characteristics of the nonwoven fabric are affected not only by the arrangement of the needles but also by their penetration density. The draft and the feed per stroke have to be coordinated as well. "Our software takes all these factors into account. We simulate and assess the penetration pattern according to the parameters entered. This enables the design engineer to determine where the needles are best placed on the needle board," says the scientist. Thanks to the new program, objective quality criteria now replace subjective assessment by the human eye. What's more, the experts have also programmed a design engineering tool. The user enters the feeds per stroke and the drafts for which he wants to construct a needle board. He specifies how wide he wants the board to be and what type of needles to use. The software then automatically comes up with a suitable needle board design.

But the development of the software posed some problems for the researchers. For example, a needle board has to be able to handle various feeds, because textile manufacturers do not produce the same nonwovens with the same feeds every day. Each needle rearrangement leads to several hours of lost production, and no manufacturer can afford that. For this reason the ITWM program has to be able to design a needle board that delivers equally well needled nonwovens for several feeds per stroke. “We managed that too,” beams Gramsch. Oerlikon Neumag Austria has now used the results of the software to build numerous new needle boards.



The density of the needle penetrations can be simulated using special software tools. (© Fraunhofer ITWM)

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Underwater robots on course to the deep sea

Research News
11-2010 I Topic 4

Even when equipped with compressed-air bottles and diving regulators, humans reach their limits very quickly under water. In contrast, unmanned submarine vehicles that are connected by cable to the control center permit long and deep dives. Today remote-controlled diving robots are used for research, inspection and maintenance work. The possible applications of this technology are limited, however, by the length of the cable and the instinct of the navigator. No wonder that researchers are working on autonomous underwater robots which orient themselves under water and carry out jobs without any help from humans.

In the meantime, there are AUVs (autonomous underwater vehicles) which collect data independently or take samples before they return to the starting points. "For the time being, the technology is too expensive to carry out routine work, such as inspections of bulkheads, dams or ships' bellies," explains Dr. Thomas Rauschenbach, Director of the Application Center System Technology AST Ilmenau, Germany at the Fraunhofer Institute for Optronics, System Technologies and Image Exploitation IOSB. This may change soon. Together with the researchers at four Fraunhofer Institutes, Rauschenbach's team is presently working on a generation of autonomous underwater robots which will be smaller, more robust and cheaper than the previous models. The AUVs shall be able to find their bearings in clear mountain reservoirs equally well as in turbid harbor water. They will be suitable for work on the floor of the deep sea as well as for inspections of shallow concrete bases that offshore wind power station have been mounted on.

The engineers from Fraunhofer Institute for Optronics, System Technologies and Image Exploitation in Karlsruhe, Germany are working on the "eyes" for underwater robots. Optical perception is based on a special exposure and analysis technology which even permits orientation in turbid water as well. First of all, it determines the distance to the object, and then the camera emits a laser impulse which is reflected by the object, such as a wall. Microseconds before the reflected light flash arrives, the camera opens the aperture and the sensors capture the incident light pulses. At the Ilmenau branch of the Fraunhofer Institute for Optronics, System Technologies and Image Exploitation, Rauschenbach's team is developing the "brain" of the robot: a control program that keeps the AUV on course in currents such as at a certain distance to the wall that is to be examined. The Fraunhofer Institute for Biomedical Engineering IBMT in St. Ingbert provides the silicone encapsulation for the pressure-tolerant construction of electronic circuits as well as the "ears" of the new robot: ultrasound sensors permit the inspection of objects. Contrary to the previously conventional sonar technology, researchers are now using high-frequency sound waves which are reflected by the obstacles and registered by the sensor. The powerful but lightweight lithium batteries of the Fraunhofer ISIT in Itzehoe that supply the AUV with energy are encapsulated by silicone. A special energy management system that researchers at the Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT in Oberhausen, Germany have developed saves power and ensures that the data are saved in emergencies before the robot runs out of energy and has to surface.

A torpedo-shaped prototype two meters long that is equipped with eyes, ears, a brain, a motor and batteries will go on its maiden voyage this year in a new tank in Ilmenau. The tank is only three meters deep, but “that's enough to test the decisive functions,“ affirms Dr. Rauschenbach. In autumn 2011, the autonomous diving robot will put to sea for the first time from the research vessel POSEIDON: Several dives up to a depth of 6,000 meters have been planned.

The torpedo-shaped underwater robot will be able to dive down to 6,000 meters. (© Fraunhofer AST)

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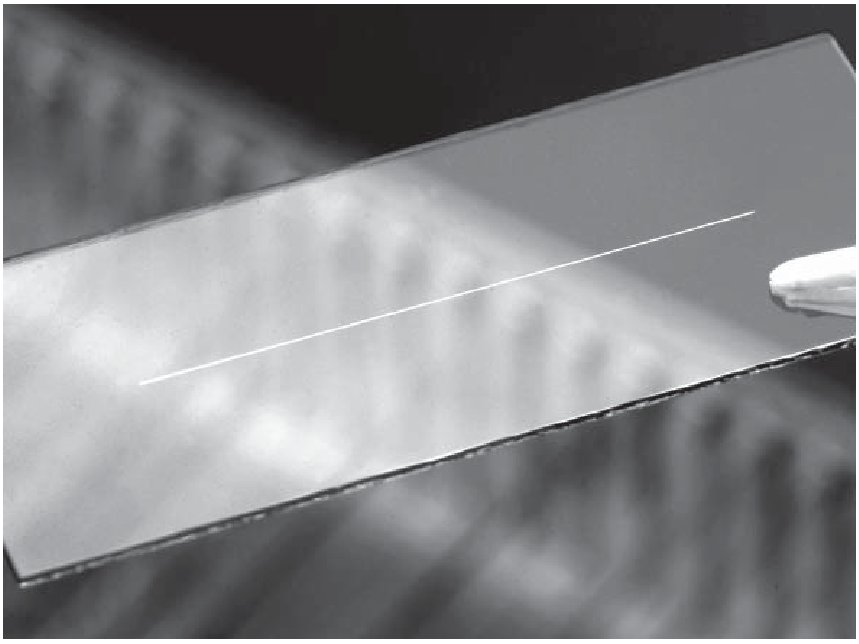
Conductor paths for marvelous light

A short push on the light switch – and the whole ceiling lights up in a uniform and pleasant color. This "illuminated sky" is not available as yet, but researchers from all over the world are working on it flat out. The technology behind this marvel is based on organic light-emitting diodes, or OLEDs for short. These diodes use special molecules to emit light as soon as current passes through them. Although the first OLEDs have only recently become available, they are small and expensive. A flat disk with a diameter of eight centimeters costs around Euro 250. Experts of the Fraunhofer Institute for Laser Technology ILT in Aachen, Germany are working together with Philips to develop a process for making these lamps distinctly bigger and cheaper – and thus suitable for mass market.

These new lamps are expensive primarily due to the costly manufacturing process. An OLED consists of a sandwich layer structure: a flat electrode at the bottom, several intermediate layers on top as well as the actual luminescent layer consisting of organic molecules. The final layer is a second electrode made of a special material called ITO (indium tin oxide). Together with the lower electrode, the ITO layer has the job of supplying the OLED molecules with current and causing them to light up. The problem is, however, that the ITO electrode is not conductive enough to distribute the current uniformly across a larger surface. The consequence: Instead of a homogeneous fluorescent pattern, the brightness visibly decreases in the center of the surface luminaire. "In order to compensate, additional conductor paths are attached to the ITO layer," says Christian Vedder, project manager at the Fraunhofer Institute for Laser Technology. "These conductor paths consist of metal and distribute the current uniformly across the surface so that the lamp is lit homogenously."

Normally the conductor paths are applied by energy-intensive evaporation and structuring processes, while only a maximum of ten percent of the luminous area may be covered by conductor paths. "The large remainder including the chemical etchant has to be recycled in a complicated process," explains Christian Vedder. This is different in the new process from the researchers from the Fraunhofer Institute for Laser Technology. Instead of depositing a lot of material by evaporation and removing most of it again, the scientists only apply precisely the amount of metal required. First of all they lay a mask foie on the surface of the ITO electrode. The mask has micrometer slits where later the conductive paths are supposed to be. On this mask the researchers deposit a thin film of metal made of aluminum, copper or silver – the metal the conductor path is supposed to be made of. Subsequently a laser passes over the conductor path pattern at a speed of several meters per second. The metal melts and evaporates while the vapor pressure makes sure that the melt drops are pressed through the fine slits in the masks on to the ITO electrode. The result are extremely fine conductor paths. At up to 40 micrometers, they are distinctly narrower than the 100 micrometer conductor paths which can be produced with conventional technology. “We have already been able to demonstrate that our methods works in the laboratory,” says Christian Vedder. “The next step is implementing this method in industrial practice together with our partner Philips and developing a plant technology for inexpensively applying the conductor paths on a large scale.” The new laser process could be ready for practical application in two to three years.



In a new process, extremely fine conductor paths can be applied to glass. (© Fraunhofer ILT)

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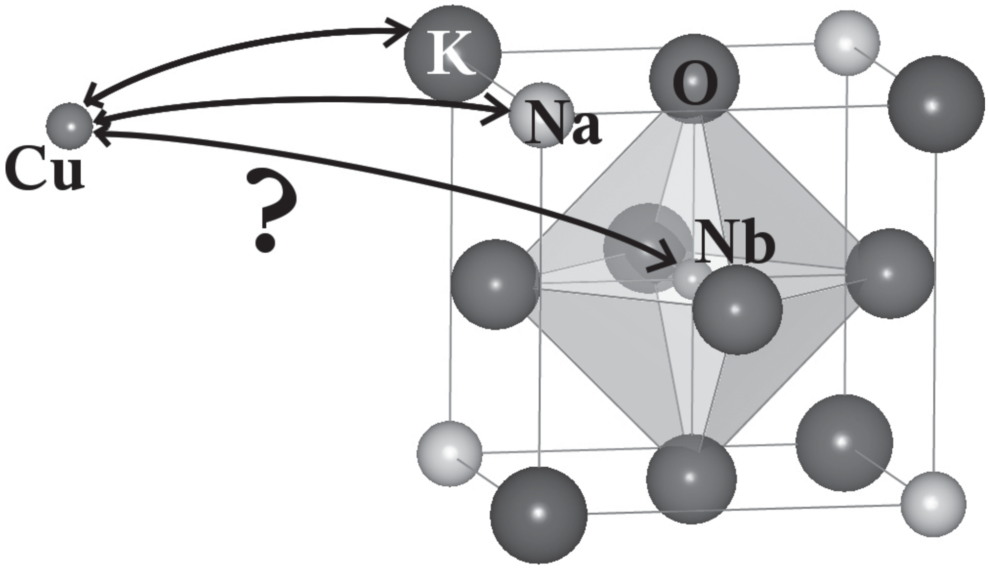
On the way to lead-free technology

Technical progress in the automobile industry is unbroken. But, the sector has still some hard nuts to crack: "Lead-free materials" is one of the challenges – hidden behind this challenge is a EU environmental directive which, based on a step-by-step plan, gradually bans all lead-containing materials and components from automotive vehicles – such as piezoelectric components. These elements are important for diesel engine injectors, for example, which control the supply of fuel to the combustion chamber.

The problem: Up to now lead-zirconate-titanate (PZT) is the material of choice when fast switchable piezoelectric applications in cars are concerned. To find alternatives without containing the heavy metal of lead is not an easy task, however, because in raw condition all alternatively used materials still do not have the desired properties. A simulation approach which the researchers of Fraunhofer Institute for Mechanics of Materials IWM have developed gets the search going now: "We have to chemically and physically modify the potential candidates in such a way that in the end the replacement materials behave similarly well as the PZT", says Professor Dr. Christian Elsässer, group leader at the IWM. A candidate such as this is potassium-sodium-niobate (KNN). Like PZT it is a ferroelectric monocrystal, but as technical ceramics with uncontrolled atom vacancies and grain boundaries in the crystal lattice, KNN is initially useless as a material. "For this reason, we have to make a virtue of necessity and have to introduce the right doping, i.e. foreign atoms, in order to improve the properties of the ceramic KNN," says Christian Elsässer.

Where and how these doping atoms have to be introduced is figured out by the researchers by means of computer simulation: Different ferroelectric properties are obtained depending at which position of the crystal lattice the foreign atoms – such as copper – are placed. "At one position, the copper donates electrons, at another position it prefers to accept them. Dipoles are formed or they are not formed depending on the lattice position," explains Christian Elsässer. These solid-state physical parameters and a number of others shall be determined in advance. Researchers do this with the help of "physics in the computer". This is by no means a trivial task because the quantum mechanical computations require complex atom model systems and big computer capacity. But on the other hand, a lot of time and money can be saved in the development of materials, because on the one hand fewer synthesis and analysis experiments in the laboratory are required. On the other hand computer simulation also produces important thermodynamic parameters for the sintering process, such as pressure and temperature ranges at which the components have to be manufactured. "The engineers receive synthesis instructions for the material at the same time," says the researcher.

In this way, the automobile industry can achieve the lead-free target faster. But not only this sector profits from Fraunhofer technology. Lead-containing materials are also present in frequency filters of mobile phone or in mechanical sensors and actuators. Ferroelectric capacitor components are competitive in the race for records when it comes to saving ever bigger data volumes on the smallest of space.



Computer simulation can calculate the possibilities of doping ferroelectric materials, such as potassium-sodium-niobate (KNN), with foreign atoms, such as copper (Cu). (© Fraunhofer IWM)

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