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RESEARCH NEWS

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1 Cameras out of the salt shaker

There have been gloves and shavers for one-off use for a long time. In future, there will also be disposable endoscopes for minimally invasive operations on the human body. A new microcamera is what makes it possible. It is as large as a grain of salt, supplies razor-sharp pictures and can be manufactured very inexpensively.

2 SmartEnergyLab: Testing smart energy systems

The residential housing sector needs smart energy systems. And yet the potential for developing these kinds of systems remains largely untapped. In the SmartEnergyLab – an innovative test laboratory – Fraunhofer researchers are able to analyze, assess and develop almost any energy management system for controlling power and heat.

3 Defective plastics repair themselves

Indestructible things are a figment of the imagination of advertising. Even plastic components that have to stand up to major mechanical loads can break. The reason for this are microcracks that may be found in any component part. Researchers have now come up with elastic polymers that heal themselves to put an end to the growth of cracks.

4 Better batteries for electric cars

The breakthrough with electric cars is a long time coming – not least on account of their key component, the battery. Lithium-ion batteries are still too expensive and their range too limited. New materials should pave the way for better batteries. Simulation software from researchers is helping speed up the development process.

5 How to help heal an injured joint

Knee patients need patience: injuries to these joints take weeks to heal. Fraunhofer researchers have now developed a system that documents the healing process in detail. This motivates patients and at the same time helps doctors to fine-tune the course of treatment.

6 Galileo Labs: better positioning with concept

Final burst for the European satellite navigation system Galileo – the first satellites are to be in position in the year 2012 and start their work. Fraunhofer Galileo Labs are showcasing the first applications that use new, improved possibilities provided by satellite navigation.

The Fraunhofer-Gesellschaft is the leading organization for applied research in Europe. Its research activities are conducted by 60 Fraunhofer Institutes at over 40 different locations throughout Germany. The Fraunhofer-Gesellschaft employs a staff of around 18,000, who work with an annual research budget totaling 1,65 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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Cameras out of the salt shaker

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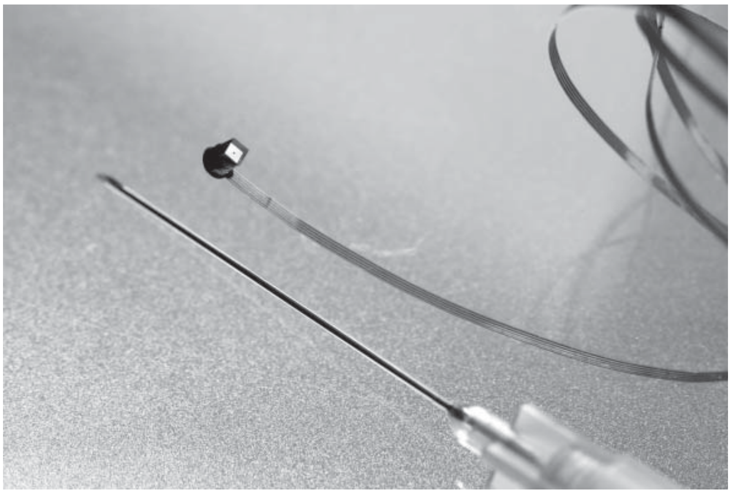
Endoscopy has gone through amazing advancements in recent years. Microcameras on the tip of endoscopes supply images from the inside of the human body in ever higher resolution, which often makes it possible to identify tumors at an early stage. Endoscopes to date have some downsides, since they are expensive and, because of their multiple usages, have to be put through time-consuming and exhaustive cleaning procedures every time they are used. This problem might be solved by a new microcamera that the Fraunhofer Institute for Reliability and Microintegration (IZM) in Berlin, Germany has developed together with Awaiba GmbH and with the support of the Fraunhofer Institute for Applied Optics and Precision Engineering IOF in Jena, Germany. Martin Wilke, a scientist at the Fraunhofer Institute for Reliability and Microintegration, says "we can produce microcameras so inexpensively with our technology that doctors can dispose of endoscopes after using them only once." This is made possible by a new type of manufacturing process.

Digital camera systems consist of two components: a lens and a sensor that transforms the image into electrical signals. Electrical contacts on the sensor allow access to these signals and therefore also to the information of the image. Due to the way they are manufactured, these contacts are located between the sensor and the lens. The sensors are manufactured simultaneously in large numbers, like computer chips. Martin Wilke says, "you have to think of a book full of postage stamps where many thousand stamps are printed in one step. If you want to use them, you have to separate one from another. Instead of a sheet of paper, with image sensors you have a circular disc of silicon that is known as a wafer." About 28,000 image sensors fit onto one wafer and until recently, each and every one was sawed out, wired and mounted on the lens that was still missing. That means wiring them 28,000 times and mounting them just as often.

The researchers at the Fraunhofer Institute for Reliability and Microintegration have streamlined this process by developing a new way to access the electrical contacts. Now, the wiring process is faster and the entire camera system is smaller. The trick lies in the fact that they do not reach the contacts of each individual image sensor via the side any more but rather, simultaneously, with all sensors via their reverse side while they are still connected as a wafer. That means that you no longer have to mount the individual lenses. Instead, you can connect them with the image sensor wafers as lens wafers. Only then is the stack of wafers sawed apart into individual microcameras. Another upside is the fact that it supplies razor-sharp pictures even with very thin endoscopes. To date, the camera systems built into them had to be divided because of their size. The lens was at the tip of the endoscope and the sensor at the other end of the glass fiber strand. The new microcamera is small enough for the tip of the endoscope. It has a resolution of 62,500 pixels and transmits the image information through the endoscope via an electrical cable. Stephan Voltz, who is the CEO of Awaiba GmbH, says that "at 1.0 times 1.0 times 1.0 millimeters, this camera is as small as coarsely ground grain of salt – the smallest camera that we are aware of."

It is not only medical technology, but also the automotive industry that is interested in this tiny camera. Presently, they are researching the possibility of replacing outside rearview mirrors on cars with microcameras. This would reduce flow resistance and energy consumption. Beyond this, installed in fittings, this camera would be able to calculate the driver's eye movements and prevent him from nodding off for a few seconds. Stephan Voltz is happy about the wide range of possible applications: "Starting in 2012, using Fraunhofer's expertise, we will be able to bring disposable endoscopes to market for only a few euros – we already have the prototype."



This new microcamera is no larger than coarsely ground salt, which is why it fits perfectly into the tip of the endoscope. (© Awaiba GmbH)

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SmartEnergyLab: Testing smart energy systems

A smartphone is all it takes to turn the heating on or off at home. This might sound like science fiction to the average user, but it is not unusual for the scientists at the Fraunhofer Institute for Solar Energy Systems ISE in Freiburg. In an innovative test laboratory, the SmartEnergyLab, they are investigating how to network various electrical household appliances and operate them remotely. In the residential housing sector in particular there is still a great deal of potential for smart energy-management systems that are capable of tailoring local power generation and consumption optimally to the power grid: What is the best time of day for utilizing solar power? How can we store the energy produced and possibly feed it back into the power grid at a lucrative price? "Smart energy-systems technology for the consumer end of the distribution grid is the key to sustainable, secure energy supply," explains Christof Wittwer, group manager at Fraunhofer ISE. By mapping all the thermal and electrical energy flows, the lab constitutes a unique platform for analyzing, assessing and developing smart homes and smart grid solutions for the distribution grid. "Basically, our lab is a simulator for potential energy systems for houses," says Wittwer.

The lab is equipped with renewable as well as electric and thermal producers and storage devices for tomorrow's single-family dwellings and apartment buildings. It boasts a stand-alone 5kW cogeneration plant, a two-cubic-meter buffer storage tank, a photovoltaic simulator, several PV inverters and various stand-alone inverters, a lithium-ion battery pack, a lead battery bank, a charging infrastructure for electric vehicles as well as other equipment. The combination of virtual and real components means researchers can simulate almost any energy system. For any given system they then assess and evaluate the potential energy savings for the customer associated with managing that system.

The service portfolio includes everything from "Integration assessment of thermal and electrical equipment in the system", "Function and communications testing for energy management systems" to the "Efficiency assessment of energy management and generation equipment". Energy suppliers and grid operators from across Germany are already leveraging the know-how of the Freiburg-based experts to determine the potential inherent in the decentralized management of this kind of equipment. Tariff models need to be assessed and their impact on the power grids investigated.

At the Hannover Messe from April 4 to 8, researchers on the joint Fraunhofer Energy Alliance booth in Hall 13, Booth C41 will be showcasing a small yet very sophisticated device: The Smart Energy Gateway – a component from the test lab – organizes the way in which data is shared between energy supplier and consumer. The smart box networks the power meters for heat, water and electricity and ensures that the right control function is used to increase efficiency based on current consumption figures and tariff information. But the Gateway is not just a networked meter and energy management optimization device: It can also be used to control household appliances or heaters and to program on/off times. When should the heat pump, the washing machine or the dishwasher come on? In future, one worry you won't have when you're on vacation is whether you forgot to switch the stove off.

The SmartEnergyLab is a simulator for possible energy systems in houses. (© Fraunhofer ISE)

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Defective plastics repair themselves

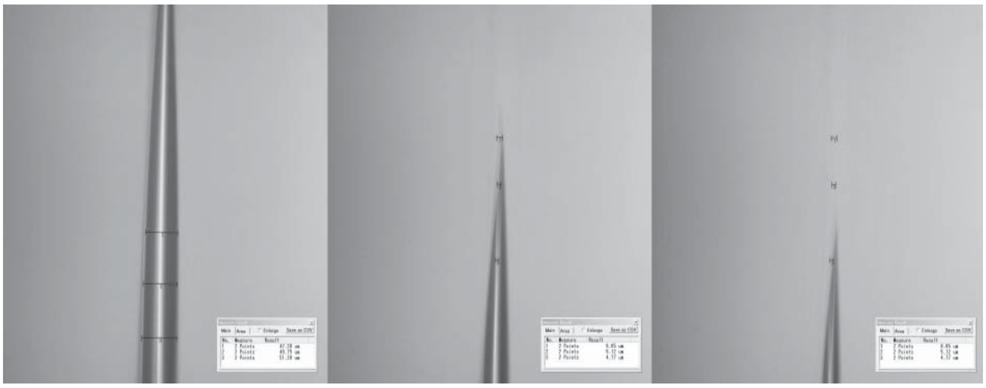
It can be a total surprise: car tires burst, sealing rings fail and even your dearly beloved panton chair or your freely oscillating plastic chair develops cracks and the material gets fatigued. The reason for this often sudden and unforeseen material failure is triggered by microcracks that may be found in any component. You may hardly see these cracks and they may grow fast or slow. This also applies to fractures in components made of plastic that can be elastically formed. Sealing rings or tires are made of these elastomers and they can withstand mechanical loads especially well.

In the OSIRIS project of the German Federal Ministry of Education and Research BMBF, researchers at the Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT in Oberhausen, Germany have come up with self-healing elastomers that can repair themselves autonomously, in order to put a stop to the growth of cracks already from the start while avoiding spontaneous material failure. The source of their inspiration was the caoutchouc tree hevea brasiliensis and plants that conduct latex, such as the Weeping Benjamin. This latex contains capsules that are filled with the protein hevein. If the caoutchouc tree is damaged, the latex escapes and the capsules break open to release hevein, which also links the latex particles in the latex to form a wound closure.

The scientists have applied this principle to elastomers. Dr. Anke Nellesen, who is a scientist at the Fraunhofer Institute for Environmental, Safety and Energy Technology, provides the explanation: "We loaded microcapsules with a one-component adhesive (polyisobutylene) and put it in elastomers made of synthetic caoutchouc to stimulate a self-healing process in plastics. If pressure is put on the capsules, they break open and separate this viscous material. Then this mixes with the polymer chains of the elastomers and closes the cracks. We were successful at making capsules stable to production, although they did not provide the self-healing effect we wanted." However, the researchers obtained good results by putting the self-healing component (i.e., the polyisobutylene) into the elastomer uncapsulised. Various test bodies from different synthetic caoutchoucs indicated clear self-healing properties, since the restored tension expansion was 40 percent after a healing period of 24 hours.

The experts even achieved better results by supplying elastomers with ions. Here, the caoutchouc tree also acted as the model for this method. The hevein proteins that are released when there is damage link up to each other through ions and stick in this process so that the crack closes. Therefore, if the elastomer material is damaged, the particles with opposite charges are looking for a new bonding partner – in other words, a plus ion attracts a minus ion, which makes it adhere. Anke Nellesen points out the advantage in relation to the microcapsule process: “We make sure that the wound closure is stable by charging the elastomers with ions, which means that the healing process can take place as often as needed. The scientist remarks that “there are already duromers with self-healing functions in the form of self-repairing paints in cars. We still haven’t developed elastomers that can close their cracks without interference from outside.”

The automobile industry could profit from this latest development, which is why you can see the prototype of self-repairing muffler suspension at the Hannover Fair in Hannover, Germany from April 4-8 at the joint Biokon stand in Hall 2.



The microcrack has gotten much smaller in as little as 30 minutes after the plastic component was supplied with ions. (© Fraunhofer UMSICHT)

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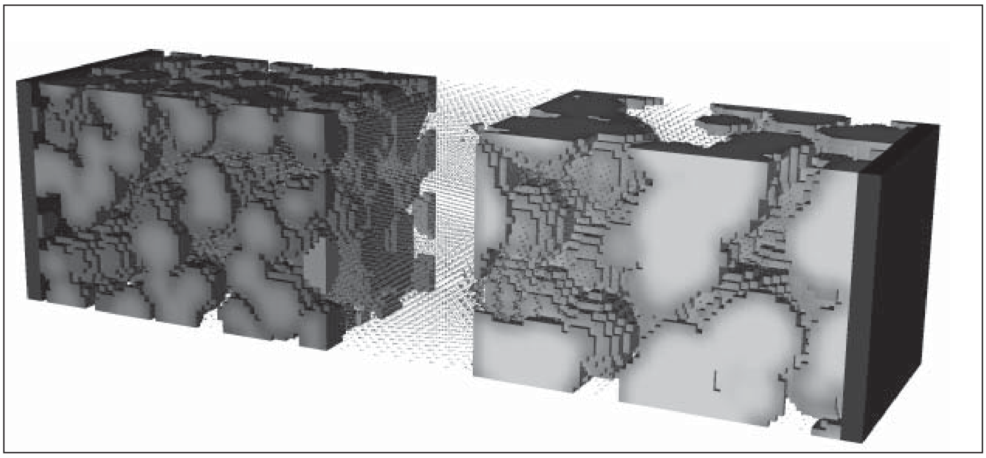
Better batteries for electric cars

Electric cars are the future – a view shared by government and the automotive industry alike. The German federal government aims to establish Germany as the lead market for electromobility. By 2020, a million passenger cars with an electric drive should be on the roads in Germany. The prospects of achieving that aim look good: As the ADAC, the German motoring organization, found out in a survey, 74 percent of those surveyed would buy an electric car if they did not have to compromise in terms of cost, comfort and safety. Consumers are not willing to compromise one iota when it comes to range. Around one third of drivers are looking for a range of at least 500 kilometers. And here is the crux: A lack of charging stations and limited battery life have so far prevented compact electric vehicles from going mainstream. The lithium-ion batteries used by most automakers are simply too heavy, too expensive and go flat too quickly. New materials should improve the performance, service life and safety of the energy storage device, yet the development of these kinds of materials is time-consuming and costly. In the Fraunhofer System Research for Electromobility (FSEM) project, researchers from the Fraunhofer Institute for Industrial Mathematics ITWM in Kaiserslautern are developing software to simulate lithium-ion batteries, which should in turn speed up this process and make it more efficient. The new software is dubbed BEST, short for Battery and Electrochemistry Simulation Tool.

A lithium-ion battery consists of two porous electrodes kept apart by a separator filled with electrolyte. Lithium ions flow between the electrodes when the battery is charged and discharged. "Battery performance depends on the materials used in the components. These materials need to work in harmony with each other," explains Jochen Zausch, a scientist in the Complex Fluids group at Fraunhofer ITWM. "Various material combinations can be simulated using our software, enabling us to come up with the ideal mix. The kind of trial-and-error testing done in the past is no longer necessary."

The Fraunhofer ITWM researchers have managed to simulate on macroscopic and microscopic level the entire battery cell as well as the transport and reaction processes of the lithium ions themselves. "We can show the microscopic structure of the electrodes. Every individual pore measuring 10 micrometers can be seen – something none of today's off-the-shelf programs can do. The position and shape of the electrodes can also be varied," says Zausch. By resolving the structure of the electrodes in three dimensions, parameters such as lithium ion concentrations and current density can be calculated. For these computations a specializes "Finite Volume" code is used that was developed and implemented at the ITWM. The distribution of the current flow provides an indication of heat production in the battery. Therefore, the software can pinpoint possible hotspots that may overheat and can lead to ignition of the battery. Aging effects can also be assessed using BEST. After all, temperature development within the battery affects its service life. The scientists intend to upgrade the program to include aging models which would make these kinds of studies even easier to conduct.

"Ultimately, BEST should help both automakers and manufacturers of electric storage devices to build robust, safe batteries with greater range and, at the same time, improved acceleration," says Zausch in conclusion. The software can be seen at the Hannover Messe from April 4 to 8 on the joint Fraunhofer booth in Hall 2, Booth D22.



Microscopic representation of the battery using the BEST simulation software. The porous electrodes can be seen on the right and left. (© Fraunhofer ITWM)

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Fraunhofer

How to help heal an injured joint

There’s nothing like the sheer delight of sun and snow on a skiing trip. But a momentary lapse of concentration can have nasty consequences. Taking a tumble on the slopes often causes injuries – most commonly to the knee. Weeks can go by before knees regain their full function, and patients are obliged to re-learn how to walk. The time it takes for the knee to heal is directly related to how well it reacts to the chosen treatment. But how is an orthopedic doctor to evaluate the healing process? And how are patients to know what progress they are making? Currently, doctors can only perform limited function tests, whilst patients are obliged to rely on their own subjective feelings. Now researchers from the Fraunhofer Institute for Manufacturing Engineering and Automation IPA in Stuttgart have developed a system for gathering exact data on knee mobility. It shows patients as well as medical staff how the joint is doing. “It not only lets sufferers see how their healing process is coming along; it also means doctors can tell straight away whether they need to adapt the treatment,” says Dipl.-Ing. Bernhard Kleiner of Fraunhofer IPA. “This can give patients a psychological boost.” They might not feel they are getting any better, but the system highlights every little improvement in knee mobility. “And that’s very motivating,” says Kleiner.

This is how the novel approach for monitoring the treatment works: Special sensors are placed in a kind of bracket that is integrated into the bandage. These register the knee’s range of movement over a period of time to determine exactly how patients are moving their knee. A new piece of software evaluates these data and presents them in an easy-to-understand format. It sounds pretty simple but it was a tough challenge for the engineers, because such angular measurement systems have only ever been used in industry up to now. The central question was how to place the sensors onto the human body without inconveniencing the patient. The answer, researchers found, lay in using lightweight materials and miniaturizing the sensors, which fall into two categories: angular measurement systems that are based on magnetic principles; and acceleration and rate-of-rotation sensors.

Depending on the injury and treatment, the system not only records the joint’s range of movement but can also determine to what degree it rotates and what forces are acting upon it. The sensors observe movements and store data non-stop. This allows doctors to observe how the knee’s range of movement changes over time, so they can recognize trends and, where necessary, adjust the treatment. What is more, the various fittings for the sensor systems have been designed by the researchers not to restrict freedom of movement in any way, meaning patients do not even notice that their joint is being monitored.

"We would like to apply the measurement of human kinematics to other parts of the body in future," says Kleiner, and the Fraunhofer researchers have already set their sights on the shoulder and the hips. However, these joints are even more demanding because the system will have to measure their movement about all three axes. To achieve this, engineers are coupling 3-D sensor systems with appropriate software. Visitors to the MEDTEC Europe trade show (March 22-24, 2011, Hall 6, Booth 6211) will have a chance to see the experts demonstrating how mobile joint monitoring works.

Sensors integrated into the bandage register the knee's range of movement. (© Fraunhofer IPA)

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Galileo labs: better positioning with concept

Whether calculating routes, finding your vehicle, tracking products or simply knowing where you are at the moment, drivers and sailors currently use satellite navigation as a matter of course and rescue personnel and logistics providers have also already discovered the potential it affords them. Up to now, the applications have mainly been based on the direction signals of the military's publicly available Global Positioning Systems (GPS). When the first four of a total of 30 satellites of the European Global Navigation Satellite System (GNSS) Galileo will be put into service in 2012, civilian users will be the main beneficiaries. "For them, the satellite navigation system will improve successively on all levels," remarked Wolfgang Inninger of the Fraunhofer Institute for Material Flow and Logistics IML in Prien. Positioning via satellite will become more reliable, more precise and safer. For one thing, the user will be able to access more satellites. Galileo will also offer a function for various services that makes it possible to check the correctness of the transmitted position data. This function makes it possible, for example, to carry out environmental impact measurements within flowing traffic. Data from these measurements can be used by the authorities only if they are "legally sound," meaning if each measurement value can be clearly attributed to a measurement site. Current GPS positioning does not provide this.

The Fraunhofer Gesellschaft's five Galileo Labs, at their sites in Berlin, Dortmund, Dresden, Erlangen and Prien respectively, demonstrate how the new possibilities of the GNSS can be used. A mobile environmental monitoring system for measuring pollutant gases and fine dust is currently being developed in the Berlin lab at the Fraunhofer Institute for Production Systems and Design Technology IPK, in cooperation with the Fraunhofer Institute for Physical Measurement Techniques IPM in Freiburg. It is intended to supplement the knowledge gained from the stationary environmental measurements with real-time traffic data. At the beginning of last year, scientists from the IML Prien and local rescue personnel successfully tested a Galileo-supported positioning system for the victims of avalanches at the Galileo test and development area (GATE) in Berchtesgaden. Eight pseudo-satellites on top of eight mountain tops emit Galileo signals during the application tests. "During this field test we located the 'avalanche victims' by within a few centimeters," reports Inninger. He estimates that the location precision could double for all GNSS applications due to the fact that there will be more satellites available. In the future, most end-user devices will be able to utilize both GPS and Galileo signals, some devices in conjunction with additional localization methods. Scientists of the Fraunhofer Institute for Integrated Circuits IIS at the Galileo lab in Erlangen are working on a combination of positioning from Galileo and WLAN signals within a building, for example, to make it easier for fire fighters to orient themselves in burning buildings. In the future, the same principle could be used to simplify the management of warehouses in commerce or in manufacturing enterprises. Logisticians at the Galileo lab in Dortmund are developing a system that fully and automatically monitors palettes by means of satellite positioning – both within and outside the warehouse.

Eight Fraunhofer institutes of the Fraunhofer Transport Alliance (www.verkehr.fraunhofer.de) perform research on GNSS applications in Galileo labs. Projects from the labs will be showcased at the Hanover Fair from April 4-8 at the Fraunhofer booth entitled "Research for the mobility of tomorrow" in Hall 2, D22.

Galileo's receiving technology distinguished itself through its very high precision. For example, the system makes it possible to detect the precise location of avalanche victims. (© Fraunhofer IML)

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