Research News

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1 Energy-autonomous sensors for aircraft

Aircraft maintenance will be easier in future, with sensors monitoring the aircraft skin. If they discover any dents or cracks they will send a radio message to a monitoring unit. The energy needed for this will be obtained from temperature difference.

2 Blood diagnosis – chip-based and mobile

The analysis takes just a few minutes and the doctor knows straight-away whether there are any pathogens in the blood. An improved marker-free technique provides the basis for faster analysis, whether in a hospital or for mobile blood donations.

3 Tracing ultra-fine dust

Limit values for fine dust emissions are based on total particle weight. It is the ultra-fine particles, however, that are particularly harmful to health. A new technique separates them by size and identifies their composition – directly where they arise.

4 Color sensors for better vision

CMOS image sensors in special cameras – as used for driver assistance systems – mostly only provide monochrome images and have a limited sensitivity to light. Thanks to a new production process these sensors can now distinguish color and are much more sensitive to light.

5 Electrostatic surface cleaning

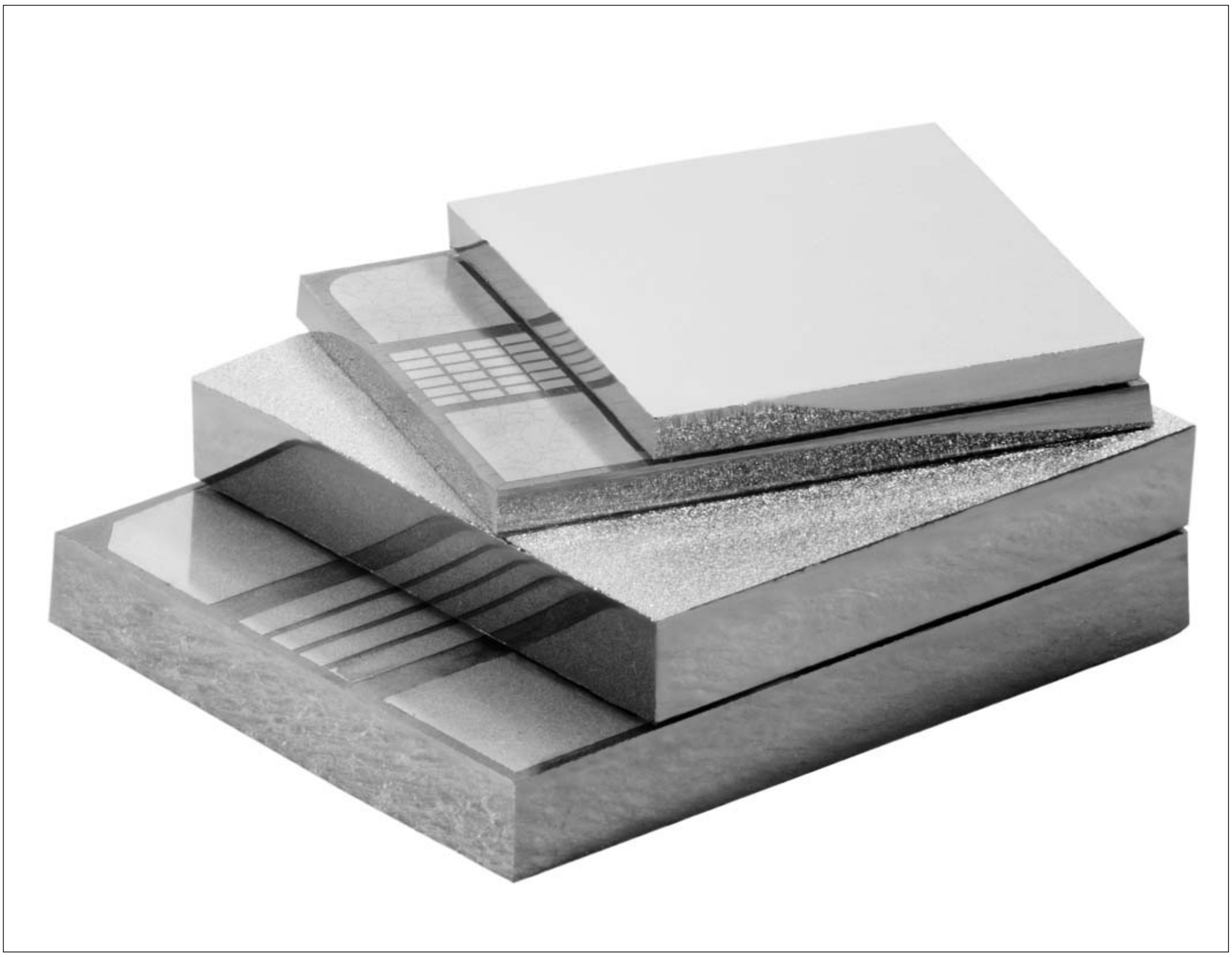
The smallest particles often make a huge difference. If they accumulate on the surface of a product during manufacturing, the quality of the goods may be impaired. A new method removes even the smallest particles safely and effectively.

6 Hollow spheres made of metal

Producing metallic hollow spheres is complicated: It has not yet been possible to make the small sizes required for new high-tech applications. Now for the first time researchers have manufactured ground hollow spheres measuring just two to ten millimeters.

7 Improved redox flow batteries for electric cars

A new type of redox flow battery presents a huge advantage for electric cars. If the rechargeable batteries are low, the discharged electrolyte fluid can simply be exchanged at the gas station for recharged fluid – as easy as refilling the petrol tank.



Sensors in the aircraft skin will simplify aircraft maintenance.

Picture in color and printing quality: www.fraunhofer.de/press

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Research News
Topic 1

No. 10 – 2009

Energy-autonomous sensors for aircraft

If a bird collides with a plane the consequences can be fatal, not only for the creature itself. The impact can deform the structure of the aircraft fuselage, causing stresses in the material which can later turn into cracks. In future, sensors in the aircraft skin will detect such damage at an early stage and simplify maintenance and repair work. The sensors are light – they don't need any cables or batteries. They draw their energy from the temperature difference between the outside air (about minus 20 to minus 50 degrees Celsius) and the passenger cabin (about 20 degrees Celsius). Because there are no batteries to change, the sensors can be located at inaccessible places on the aircraft.

EADS Innovation Works heads the development consortium. Researchers at the Fraunhofer Institute for Physical Measurement Techniques IPM in Freiburg are developing the energy supply system for the sensors. "We use thermoelectric generators, developed in cooperation with Micropelt GmbH, and adapt them so that they work efficiently," explains Dr. Dirk Ebling, scientist at the IPM. Thermoelectric materials are semiconductors which generate electric power under the influence of a temperature difference. If a number of these thermoelectric elements are connected in series, enough energy is produced to power small sensors as well as a radio device transmitting the measurement results to a central unit. "We are also optimizing the heat flow," the research scientist continues. A key question is how to couple the thermoelectric generator to the warm and cold environments so that it transports enough heat. To obtain the answer the scientists set up a climate chamber in which the temperature profile of the aircraft fuselage is simulated. The first optimized prototypes have already been built. Development of a prototype of the entire system including the sensor, thermoelectric generator, energy storage device, charging electronics and signal transmission module is scheduled for completion in about three years' time, hopefully enabling the system to enter series production.

The applications for energy-autonomous sensors are numerous. In automobiles they could help to reduce weight by removing the need for heavy cable assemblies. They would also be useful in old buildings, where they could be easily affixed to walls e.g. to monitor dampness. Their use in the medical sector is feasible too. A sensor system integrated in a running shirt could monitor an athlete's pulse during training, and hearing aids could obtain their energy from body heat.

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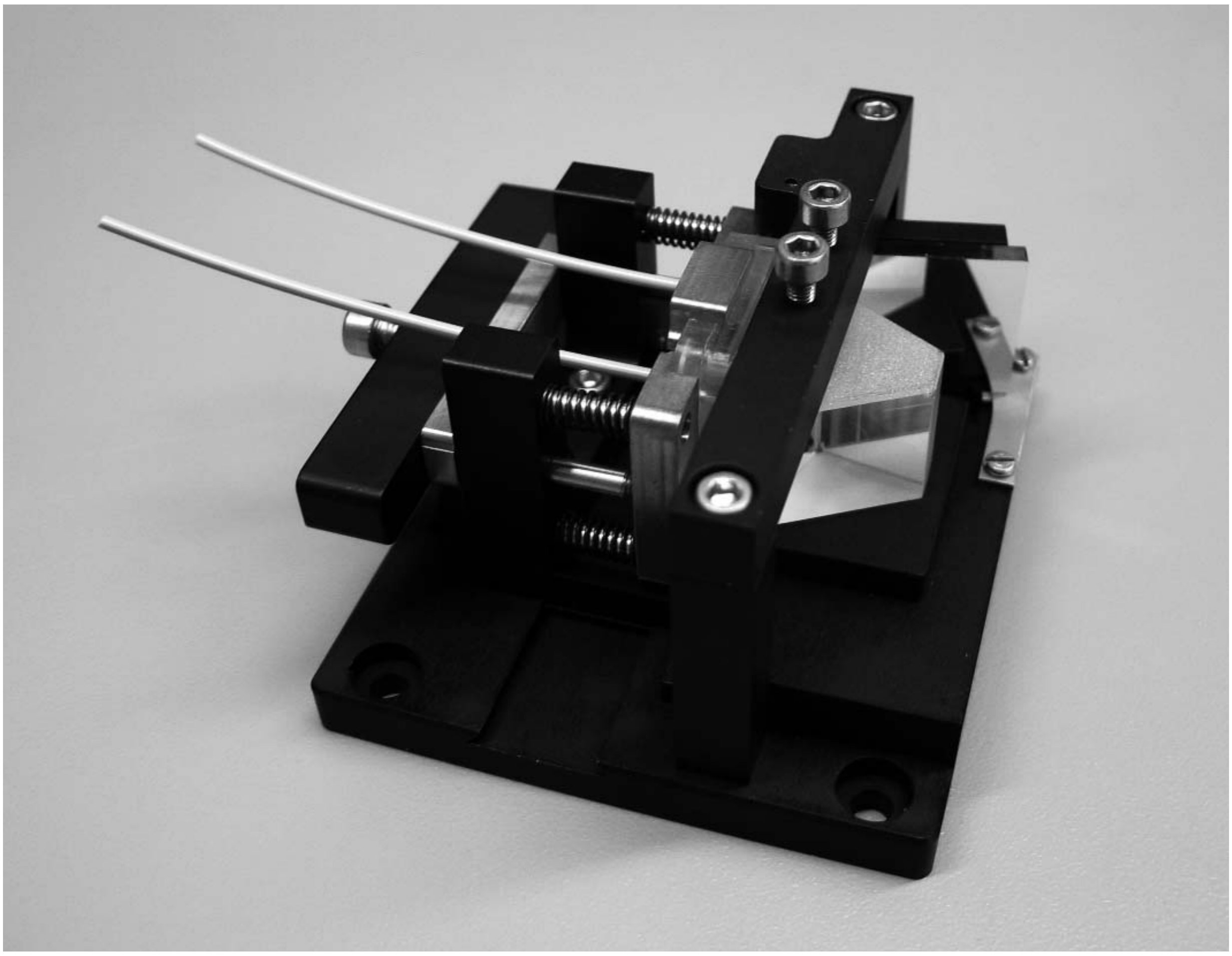

This unit houses the encapsulated measurement chip with which blood samples can be tested on site for pathogens.

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No. 10 – 2009

Blood diagnosis – chip-based and mobile

If a person loses a large amount of blood the consequences can be critical. That's why adequate quantities of donated blood have to be kept available in hospitals and blood banks. In Egypt doctors collect blood by traveling to towns and villages and conducting blood donation sessions in a laboratory bus. The problem is that 25 per cent of the samples taken contain pathogens, including HIV, hepatitis and syphilis. As these diseases can be passed on in transfusions, the contaminated blood cannot be used. Conventional fast tests are not suitable in most cases for mobile use.

In future a rapid and robust analysis technique could help. A few drops of blood could be tested in the bus to check whether it can be used. Only if the result is positive will the doctors take a larger quantity from the donor. The basis for this has been provided by research scientists at the Fraunhofer Institute for Biomedical Engineering IBMT in Sankt Ingbert under an EU project also involving the Egyptian company VACSERA, Mivitec GmbH, the Institute for Analytical Sciences ISAS in Dortmund and the University of Lausitz. “Our consortium has developed a glass chip which has antibodies on it. Tiny surface oscillations are induced in the chip. If the relevant virus binds with an antibody, the oscillation changes,” explains Dr. Thomas Velten, Head of Department at the IBMT. The technique is not new, but the chip that has been developed offers advantages. Usually there is only one measurement field and a reference field next to it, positioned a just a few millimeters apart. But the temperature there can be different. On the new chip, the measurement and reference fields are divided into narrow strips which in each case are located right next to each other. As a result the chip is more resistant to fluctuations in temperature. What’s more, the new chip consists of four analysis squares, which means that the blood can be examined for four different pathogens during each test.

It has also been difficult up till now for laboratory workers to avoid contact with the blood and protect themselves from infections while conducting tests in the bus. The researchers at the IBMT have therefore encapsulated the chip. This makes the blood follow a defined course on the chip, protecting the user. A first prototype of the measurement device is being presented at the Medica trade fair from November 18 to 21 in Düsseldorf (Hall 10, Stand 10F05). Dr. Velten estimates that the device could come onto the market in about three years' time.

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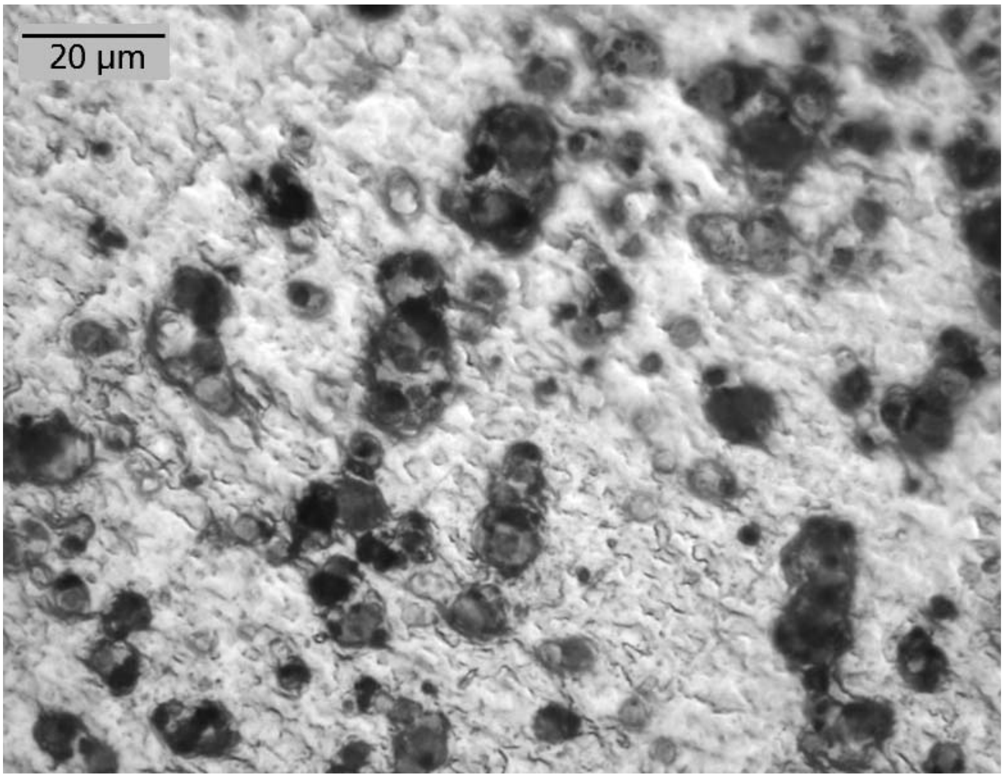

Microscope image of dust particles collected on a filter.

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Research News
Topic 3

No. 10 – 2009

Tracing ultra-fine dust

Fine particle emissions have been the subject of heated debate for years. People who live near industrial plants see the smoke being discharged into the atmosphere and wonder how harmful it is. But visible emissions are not always the most harmful. The highest risk is posed by fine dust particles which can easily penetrate the human organism. These ultra-fine particles are difficult to measure, however, because they are less than 100 nanometers in diameter.

Research scientists at the Fraunhofer Institute for Laser Technology ILT in Aachen have developed a technique by which the composition of such particles can be precisely analyzed. “The statutory limit values for fine particle emissions are based on the total particle weight,” explains Dr. Cord Fricke-Begemann, project manager at the ILT. “Large particles are, however, much heavier than small ones. Weight measurements do not provide any information on the quantity of ultra-fine particles in the fine dust, but they are often more harmful than the larger particles.”

The measurement technique developed by the research scientists consists of two steps. A gas stream separates the particles into size classes before they are collected on filters. Their composition is then examined by means of laser emission spectroscopy. “We are therefore able to identify harmful heavy and transition metals, such as zinc, in the fine dust, and also to ascertain the particle size at which they become particularly enriched,” explains Fricke-Begemann. A key aspect of the method is that it delivers the results in less than 20 minutes. What’s more, it can work at a high throughput rate and enables measurements to be taken directly on site – e.g. in steel plants. Emission values can be measured and monitored in real time during production thanks to a further development of the technique in which the particles are continuously drawn off via an air tube and analyzed.

All industrial plants produce fine dust emissions, and every process leaves behind a characteristic “fingerprint” of the particle composition and size distribution. With their measurement method the scientists can test the air in nearby residential areas and identify where the particles are from. They can also help to develop strategies for reducing emissions from the plants concerned.

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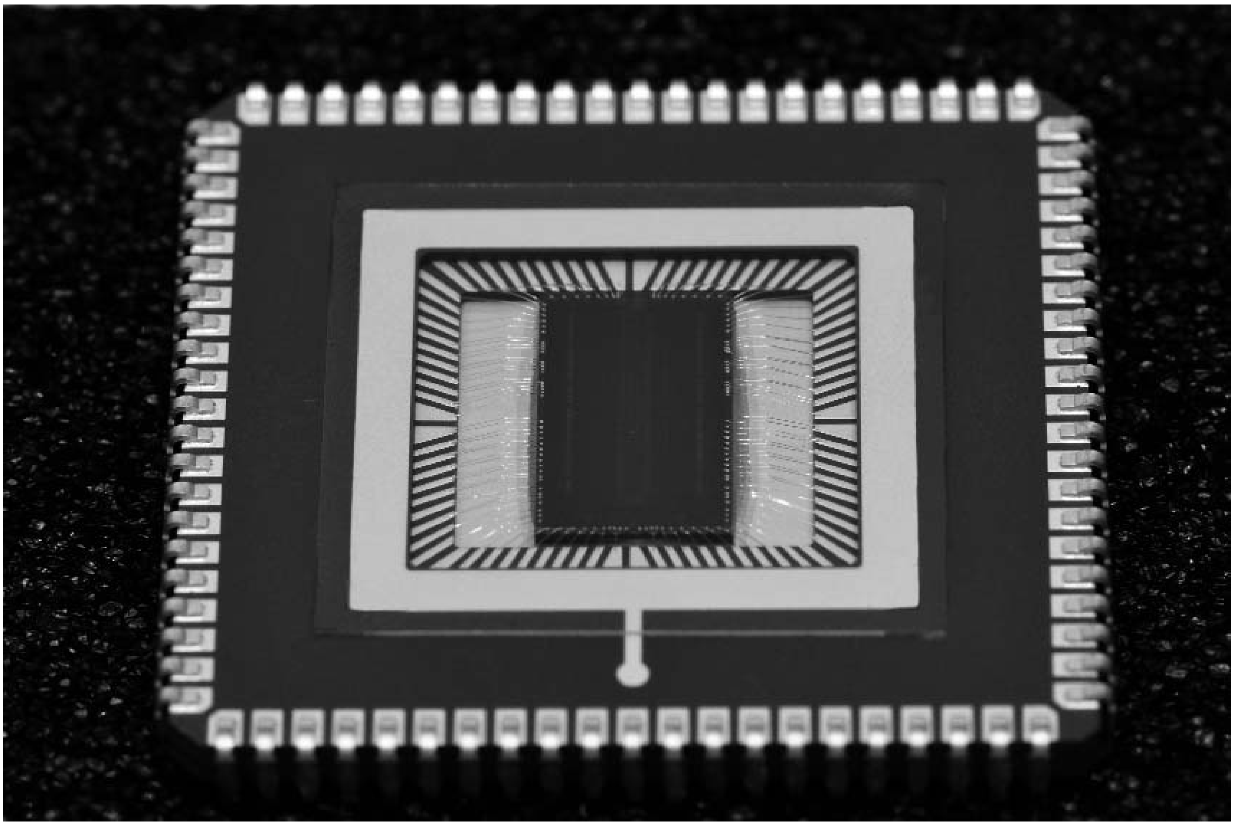

The innovative CMOS image sensor can distinguish color and is much more light-sensitive than conventional sensors.

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No. 10 – 2009

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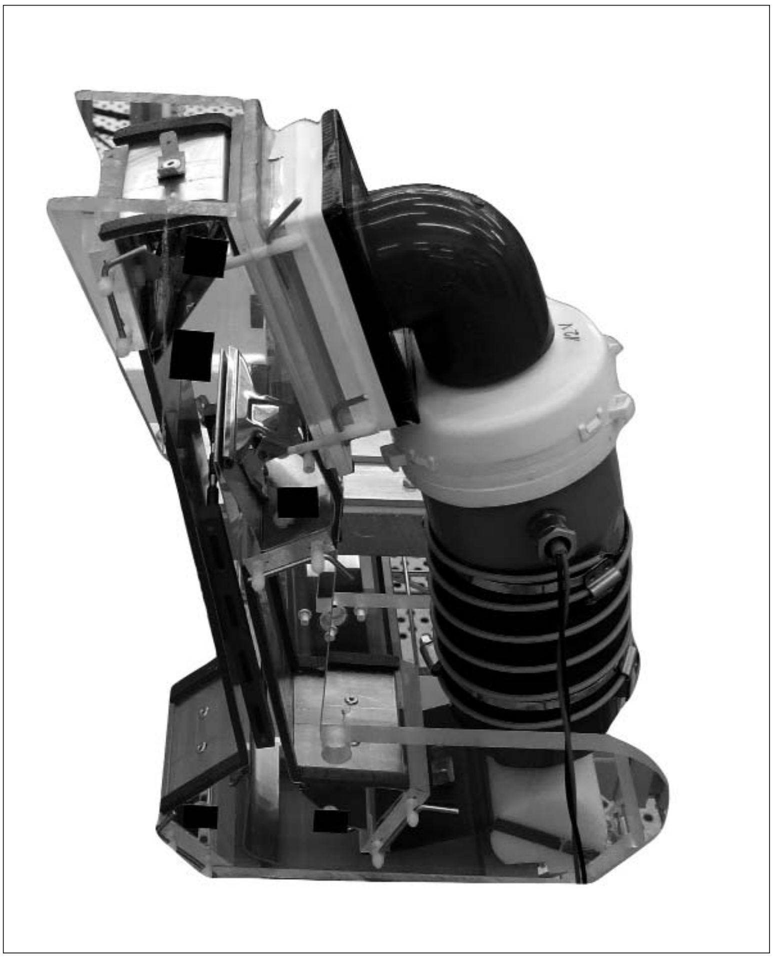
Color sensors for better vision

The car of the future will have lots of smart assistants onboard – helping to park the car, recognize traffic signs and to warn the driver of blind spot hazards. Many driver assistance systems incorporate high-tech cameras which have to meet a wide range of requirements. They must be able to withstand high ambient temperatures and be particularly small, light and robust. What's more, they have to reliably capture all the required images and should cost as little as possible. Nowadays CMOS sensors are used for most in-car systems. These semiconductor chips convert light signals into electrical pulses and are installed in most digital cameras. At present, however, the sensors used for industrial and other special cameras are mostly color blind.

Now researchers at the Fraunhofer Institute for Microelectronic Circuits and Systems IMS in Duisburg are adding some color to the picture. They have developed a new process for producing CMOS image sensors which enables the chips to see color. Normally the image sensors are produced on silicon wafers using a semiconductor technique, the CMOS process. "We have integrated a color filter system in the process," explains Prof. Dr. Holger Vogt, Deputy Director of the IMS. "In the same way as the human eye needs color-specific cone types, color filters have to be inserted in front of the sensors so that they can distinguish color." This job is handled by polymers dyed in the primary colors red, green and blue. Each pixel on the sensor is coated with one of the three colors by a machine which coats the sensor disk propels with a micrometer-thick polymer layer. Using UV light and a mask which is only transparent on the desired pixels, the dye is fixed at the requisite points and the rest is then washed off. In addition, the researchers have developed special microlenses which help the sensor to capture and measure the light more efficiently. With the aid of a transparent polyimide they create a separate lens for each individual pixel, which almost doubles the light-sensitivity of the image sensor.

The optimized CMOS process not only makes it possible to cost-efficiently improve the performance of driver assistance systems. Endoscopes can also benefit from the new properties of CMOS image sensors. The researchers are presenting the CMOS process at the Vision trade fair from November 3 to 5 in Stuttgart (Hall 6, Stand 6D12).



The equipment removes fine dust particles effectively from product surfaces – and collects them safely.

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Research News
Topic 5

No. 10 – 2009

Electrostatic surface cleaning

It's often the little things that count in industrial manufacturing processes. Particles less than half the diameter of a hair in size can significantly impair quality in production. For example, there should be no particles larger than five micrometers on the packaging film of food and medicines, as these could contaminate the contents. Tiny particles also cause problems in the printing industry, as they reduce the quality of the print if they remain on the surface of the paper. And fine particles on electrical components can cause operational failures. Manufacturers usually resort to a type of vacuum cleaner to remove the dust – it blows air on the contaminated surface, then sucks this in again, together with the undesired particles. However, this method does not effectively remove particles smaller than 20 micrometers, as the electrostatic force causes the majority of them to remain on the surface.

Researchers at the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB in Stuttgart have developed a system which also removes these fine dust particles effectively from the product surfaces. Colleagues from NITO A/S in Denmark, Ziegener + Frick GmbH in Ellhofen and the Danish Innovation Institute were involved in the development process. "The system guarantees the quality of the product and improves the working environment of employees, as it reliably collects the harmful particles, preventing them from going into the air and then into the lungs of employees," says Sukhanes Laopeamthong, a researcher at the IGB.

The researchers charge the dust particles with positive ions. A negatively charged electrode attracts the positively charged dust particles, the resulting force lifting the dust particles easily from the surface of the product. A controlled air current carries them to the dust collector. Prior to the construction of the test equipment, the researchers have already resolved a few questions using special simulation software. What electrical field strength is required to lift the dust particles? What are the required characteristics of the air current transporting the particles? The test equipment removes on average 85 percent of dust particles smaller than 15 micrometers and more than 95 percent of dust particles bigger than 15 micrometers. The researchers are presenting the exhibit at the Parts2Clean trade fair from 20 to 22 October in Stuttgart (hall 1, stand F 610/G 709). The scientists expect the system to be operational in industry in approximately two years.

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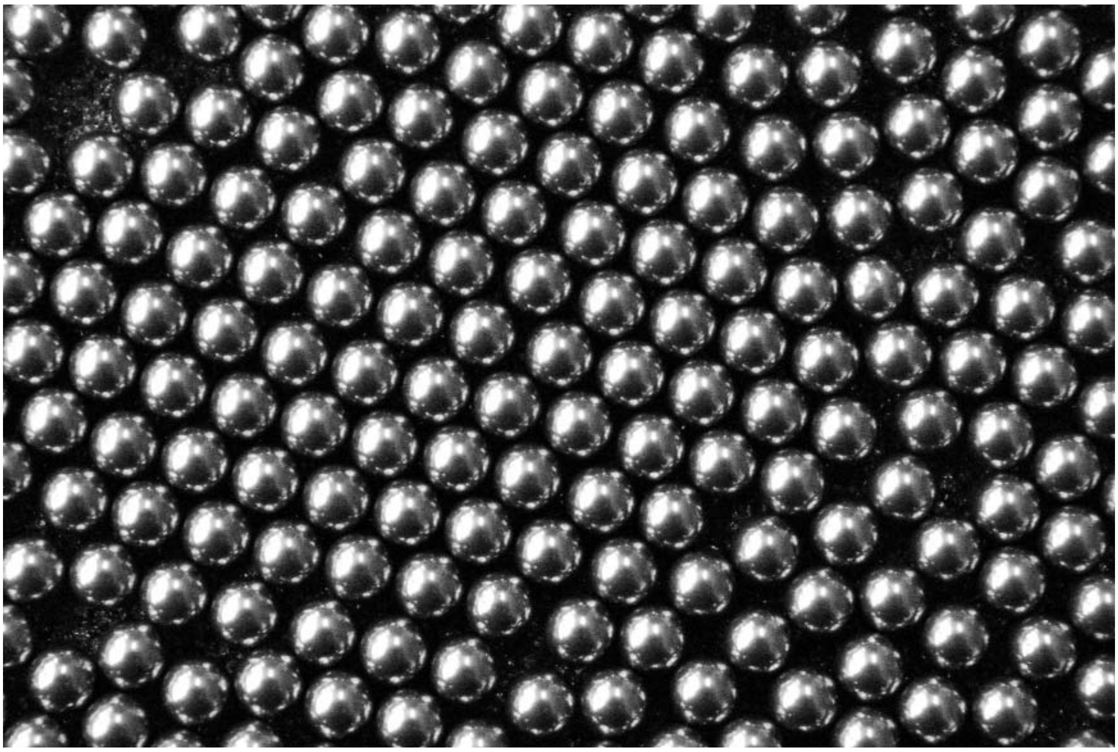

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Hollow spheres made of ground steel, measuring just two to ten millimeters.

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Research News
Topic 6

No. 10 – 2009

Hollow spheres made of metal

New drive technologies combined with lighter and stronger materials will make the airplanes and automobiles of the future more fuel-efficient. But a number of technical details need to be resolved first. Magnetic ball valves are one example – for them to react extremely quickly, the balls must be as light as possible, and the same applies to rapidly moving bearings. Hollow spheres made of steel represent a solution.

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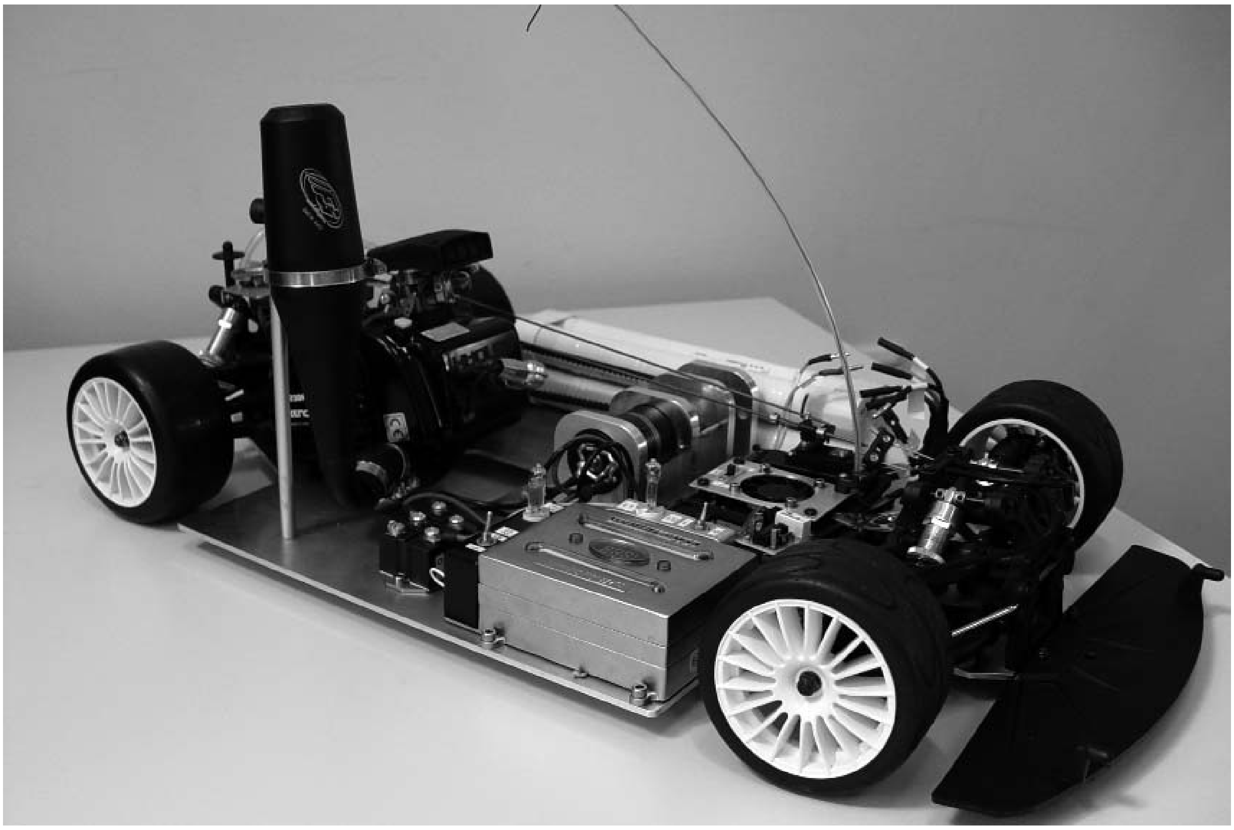
Researchers at the Fraunhofer Institute for Manufacturing and Advanced Materials IFAM in Dresden working in cooperation with hollomet GmbH Dresden have created the technology for the manufacture of rapidly reacting ball valves and bearings. "In an injection valve the movement of a ball causes the valve to open and close. The lighter the ball, the quicker it moves," explains Dr.-Ing. Hartmut Göhler, project manager at the IFAM. Until now it has only been possible to produce balls of this size as solid spheres, but a solid body is relatively heavy and therefore reacts slowly in a ball valve. "For the first time we've been able to produce metal hollow spheres in the required diameter of just two to ten millimeters. The hollow spheres are 40 to 70 percent lighter than solid ones." The process starts with polystyrene balls which are lifted up and held by an air current over a fluidized bed while a suspension consisting of metal powder and binder is sprayed onto them. When the metal layer on the balls is thick enough, heat treatment begins, in which all the organic components, the polystyrene and the binder evaporate. The residual materials are gaseous and escape through the pores in the metal layer. A fragile ball of metal remains. This is now sintered at just below melting temperature, and the metal powder granules bind together, forming a hard and cohesive shell. The sphere is now stable enough to be ground in a machine, but the pressure must not be too high as otherwise the hollow body will deform. The wall thickness can be set to between a few tenths of a millimeter and one millimeter.

Göhler sees applications for the technique wherever a low mass inertia is required. "Hollow spheres will create applications which have not been possible up to now," Göhler states. The scientists have already produced ground spheres made of steel, other metals such as titanium and various alloys are envisaged for the future.



The test vehicle into which researchers are integrating a redox flow battery.

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No. 10 – 2009

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Improved redox flow batteries for electric cars

Electric mobility is becoming increasingly important. The German government's ambitious plan envisages one million electric cars being sold in Germany by the year 2020. Until then, however, researchers still have to overcome some hurdles, such as the question of energy storage. Lithium-ion batteries offer a possible solution, but it takes hours to charge them – time that an automobile driver doesn't have when on the road. Researchers from the Fraunhofer Institute for Chemical Technology ICT in Pfinztal near Karlsruhe see an alternative in redox flow batteries. "These batteries are based on fluid electrolytes. They can therefore be recharged at the gas station in a few minutes – the discharged electrolyte is simply pumped out and replaced with recharged fluid," says engineer Jens Noack from ICT. "The pumped-off electrolyte can be recharged at the gas station, for example, using a wind turbine or solar plant."

The principle of redox flow batteries is not new – two fluid electrolytes containing metal ions flow through porous graphite felt electrodes, separated by a membrane which allows protons to pass through it. During this exchange of charge a current flows over the electrodes, which can be used by a battery powered device.

Until now, however, redox flow batteries have had the disadvantage of storing significantly less energy than lithium-ion batteries. The vehicles would only be able to cover about a quarter of the normal distance – around 25 kilometers – which means the driver would have to recharge the batteries four times as often. "We can now increase the mileage four or fivefold, to approximately that of lithium-ion batteries," Noack enthuses. The researchers have already produced the prototype of a cell. Now they must assemble several cells into a battery and optimize them. This further development is being carried out with colleagues from the University of Applied Sciences, Ostphalia, in Wolfenbüttel and Braunschweig. They are testing electric drives and energy storage units on model vehicles that are only a tenth of the size of normal vehicles. The research team has already built a traditional redox flow battery into a model vehicle. A vehicle on a scale of 1:5 can be seen in action on a test rig set up at the eCarTech in Munich (Hall C3, Stand 424) from 13 to 15 October. In the coming year the researchers also want to integrate the new battery, with four times greater mileage, into a model vehicle.

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