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Research News

No. 1 – 2009

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1 A Robot Inspects Wind Energy Converters

The material of wind energy converters must withstand intense forces. Are rotor blades damaged? A new robot inspects wind energy converters more precisely than a human ever could. It detects the minutest damage – even below the surface.

2 Electronics from the printer

Electronic systems designed to perform simple functions, such as monitor the temperature on a yogurt pot, mustn't cost much: This is where printed electronics are at an advantage. Researchers are now significantly improving the properties of printed circuits.

3 Flat fixtures for EUV exposure

Exposing silicon wafers to light during chip manufacture requires special fixtures called chucks. Novel electrostatic chucks made of glass ceramics are incredibly flat. This prevents structural distortions on the exposure mask and the silicon chip.

4 Sensor in artery measures blood pressure

High blood pressure can be a trial of patience for doctors and for sufferers, whose blood pressure often has to be monitored over a long time until it can be regulated. This will now be made easier by a pressure sensor that is inserted in the femoral artery.

5 Precious coatings for plastic parts

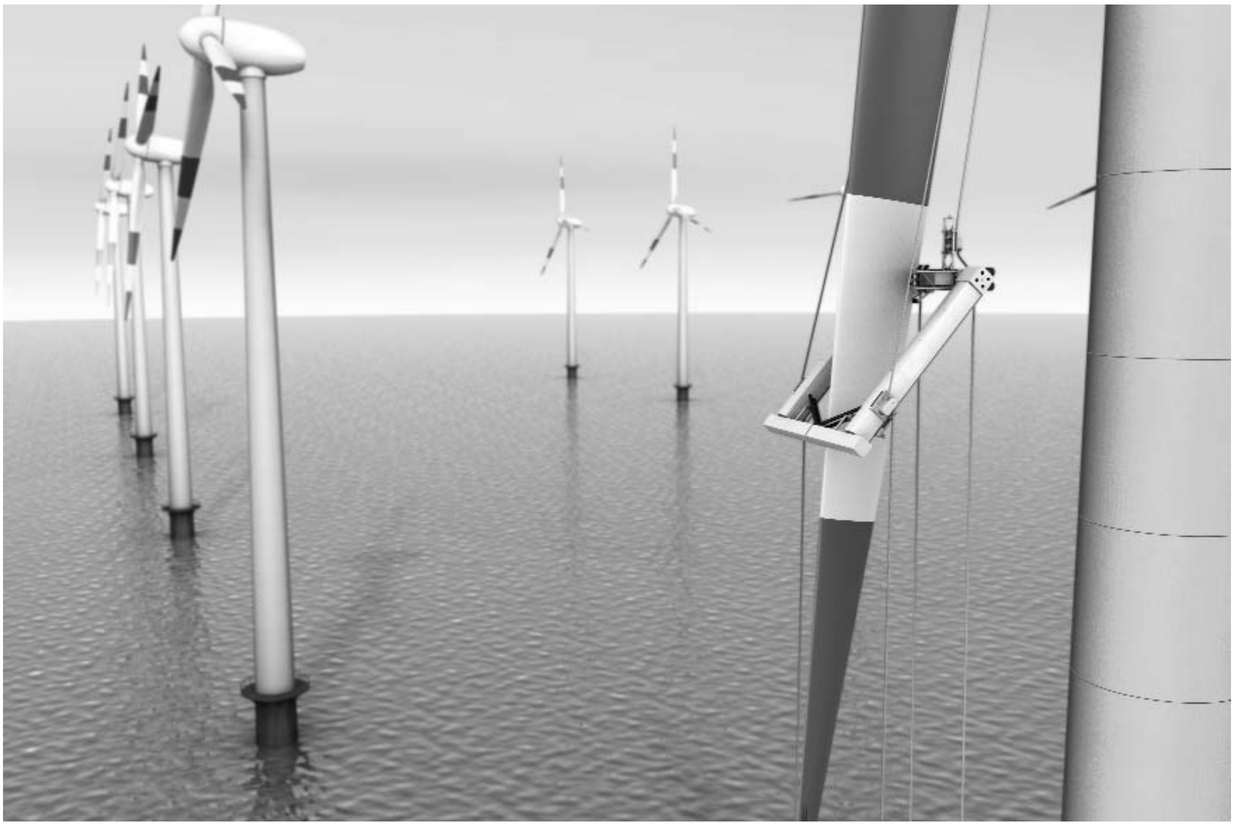
Bearings are universal components. Few devices can do without them. A diamond-like coating reduces friction in ball and slide bearings: The carbon layer can be applied to the plastic cage using a special process, and increases the components' resilience and life span.

6 Safely fixed hip prostheses

Artificial hip joints are firmly anchored to the patient's damaged bone by screws. But which parts of the bone will safely hold the screws in place? A simulation model is to calculate the strength of the bone from computer tomography images.

7 Hybrid foams and lightweight constructions

A special process will make it possible to improve the mechanical, thermal and acoustic properties of foams in the future. This will be of particular benefit to lightweight construction.



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A robot inspects a wind energy converter's rotor blades for possible damage.

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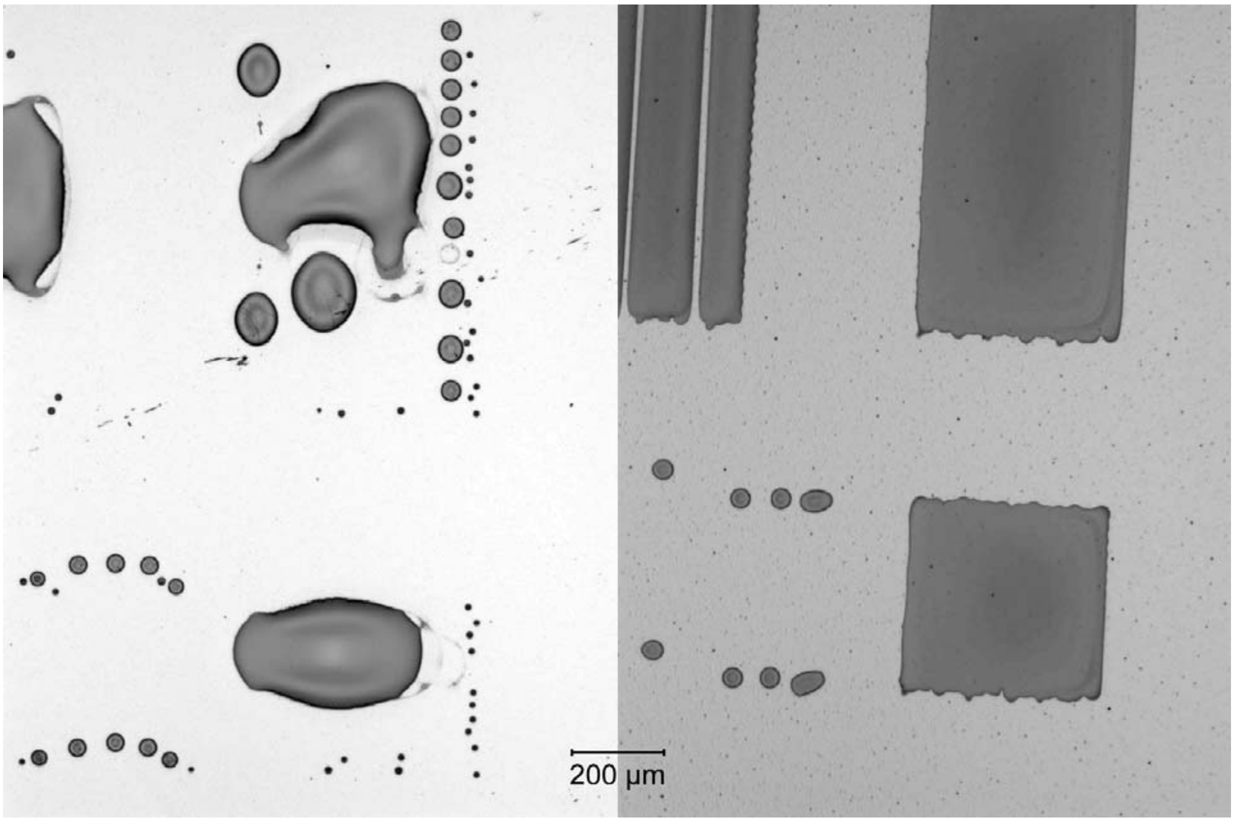
A Robot Inspects Wind Energy Converters

It appears reliably and appears alone. Nimbly and quickly, it pulls itself up a rope meter for meter until it reaches a wind energy converter's giant rotor blades. Then it goes to work. It thoroughly inspects every centimeter of the rotor blades' surface. Nothing escapes it. It registers any crack and any delamination in the material and relays their exact positions. In this job, a robot is superior to humans.

The researchers at the Fraunhofer Institute for Factory Operation and Automation IFF are experts in robotics – regardless of whether to clean facades, inspect sewer lines or assist humans. Their latest helper is RIWEA, a robot that inspects the rotor blades of wind energy converters. Primarily made of glass fiber reinforced plastics, rotor blades have to withstand a great deal: wind, inertial forces, erosion, etc. Until now, humans have inspected wind energy converters at regular intervals – not an easy job. After all, the technicians must closely examine large surfaces – a rotor blade can be up to 60 meters long – in airy heights. "Our robot is not just a good climber," says Dr. Norbert Elkmann, Project Manager am Fraunhofer IFF and coordinator of the joint project. "It is equipped with a number of advanced sensor systems. This enables it to inspect rotor blades closely." Are there cracks in the surface? Are the bonded joints and laminations in order? Is the bond with the central strut damaged?

The inspection system consists of three elements: An infrared radiator conducts heat to the surface of the rotor blades. A high-resolution thermal camera records the temperature pattern and thus registers flaws in the material. In addition, an ultrasonic system and a high resolution camera are also on board, thus enabling the robot to also detect damage that would remain hidden to the human eye. A specially developed carrier system ensures that the inspection robot is guided securely and precisely along the surface of a rotor blade. "it is a highly complex platform with sixteen degrees of freedom, which can autonomously pull itself up ropes," explains Elkmann. The advantage of this system: It can perform its job on any wind energy converter – regardlesss of whether it is large or small, on land or offshore. The robot always delivers an exact log of the rotor blades' condition, keeping humans safe and not missing any damage.



In order for printed electron devices to work, the researchers need to match the properties of the ink and the substrate surface to one another. The untreated insulator (left) is difficult to wet, unlike the surface-treated insulator (right).

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Electronics from the printer

Televisions have changed dramatically: While bulky TV sets dominated our living rooms until just a few years ago, the screens are now so flat that they can easily be hung on the wall. A close look at the inside of these devices will reveal fine conductor paths and transistors that supply the electricity needed to switch the pixels on the screen on and off. These circuits are manufactured layer by layer, usually by photolithography. The materials are deposited onto the entire surface of a substrate and covered with photoresist, which is exposed to light at specific points using a mask. The exposed photoresist alters its chemical properties: It becomes soluble and can be easily removed. The layer to be structured returns to the surface and can be etched away. However, the parts of the layer still covered with photoresist remain intact. One major disadvantage of this process is that a large fraction of the deposited material is not used. A more cost-efficient and resource-saving method is to deposit the material by printing only in places where it will actually be needed later.

Printed electronics already exist in the form of conductor paths and devices made from polymers. However, their electrical properties cannot compete with those of inorganic materials. The charge carriers in the polymers travel more slowly, with the result that a printed RFID tag, for example, will have a shorter transmission range than a conventional one. Moreover, polymers tend to react more sensitively to moisture and UV light. Researchers at the Fraunhofer Institute of Integrated Systems and Device Technology IISB in Erlangen have now commissioned a process line in which electron devices can be printed from inorganic materials using an ink jet similar to those in any office printer. "We use ink made of nanoparticles and add a stabilizer so that the particles can be easily processed and do not clump together," says IISB group manager Dr. Michael Jank.

The nano ink has passed the first printing tests and Jank hopes that the researchers will be able to print circuits performing simple functions in about a year's time. "We expect printed products to cost around 50 percent less than silicon-based ones in the case of simple circuits," he says. "Printed RFID tags should then be cheap enough to be attached to the packaging of low-cost products such as yogurts, where they can then monitor the temperature, and store and transmit data."

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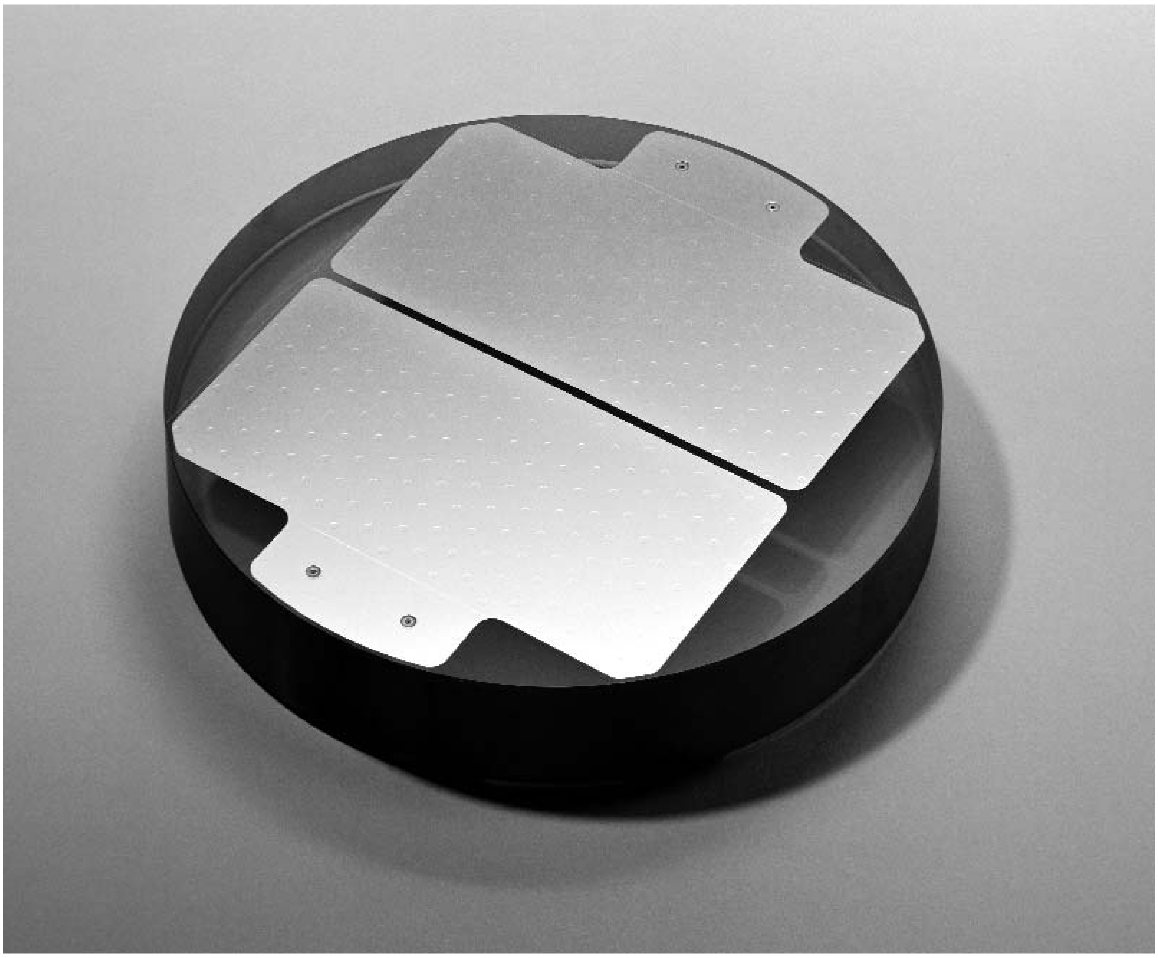

The EUV mask chuck will support the manufacture of silicon chips in the future: It holds the bent exposure mask in place overhead and almost perfectly levels it.

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Flat fixtures for EUV exposure

Smaller, even smaller, tiny. Miniaturization in chip manufacture is progressing at an impressive pace. Researchers continue to push the physical limits of semiconductor technology and are developing methods of making circuit elements even smaller and faster. At the same time, the associated processes are having to meet increasingly high requirements.

The experts predict a promising future for EUV lithography – lithography with extremely shortwave ultraviolet light. This works as follows: Light with a wavelength of 13 nanometers is guided through a reflection mask onto the silicon wafers, where it generates nanometer structures. As the exposure processes take place in a vacuum, special fixtures are necessary to accommodate the silicon wafers and the exposure mask, and to hold them firmly in place. The technical term for these is chucks. Researchers at the Fraunhofer Institute for Applied Optics and Precision Engineering IOF have developed exceptionally precise electrostatic chucks for EUV lithography. "The chucks need to be extremely smooth and even," says Fraunhofer IOF scientist Dr. Gerhard Kalkowski. "If they are not super-flat, the result is height deviations in the mask, which lead to structural distortions on the silicon chips." The IOF researchers are using special glass materials and have developed new technologies to increase the levelness of the chucks, with excellent results: While height deviations of over 100 nanometers had been measured previously, the new material reduced them to 74 nanometers, setting a new record. The chuck and the mask virtually merge into a single plane. The IOF chucks also have other advantages: "The material guarantees high holding strengths, distributed across the entire surface, and reduces abrasion," says Kalkowski. Two properties of great importance to the EUV exposure process.

The researchers' findings will greatly benefit the chip industry, as chip manufacturers rely particularly on the stability and precision of the chucks in order to be able to use EUV lithography in mass production. Meanwhile, the IOF researchers are working towards their next goal: flatter than 50 nanometers.

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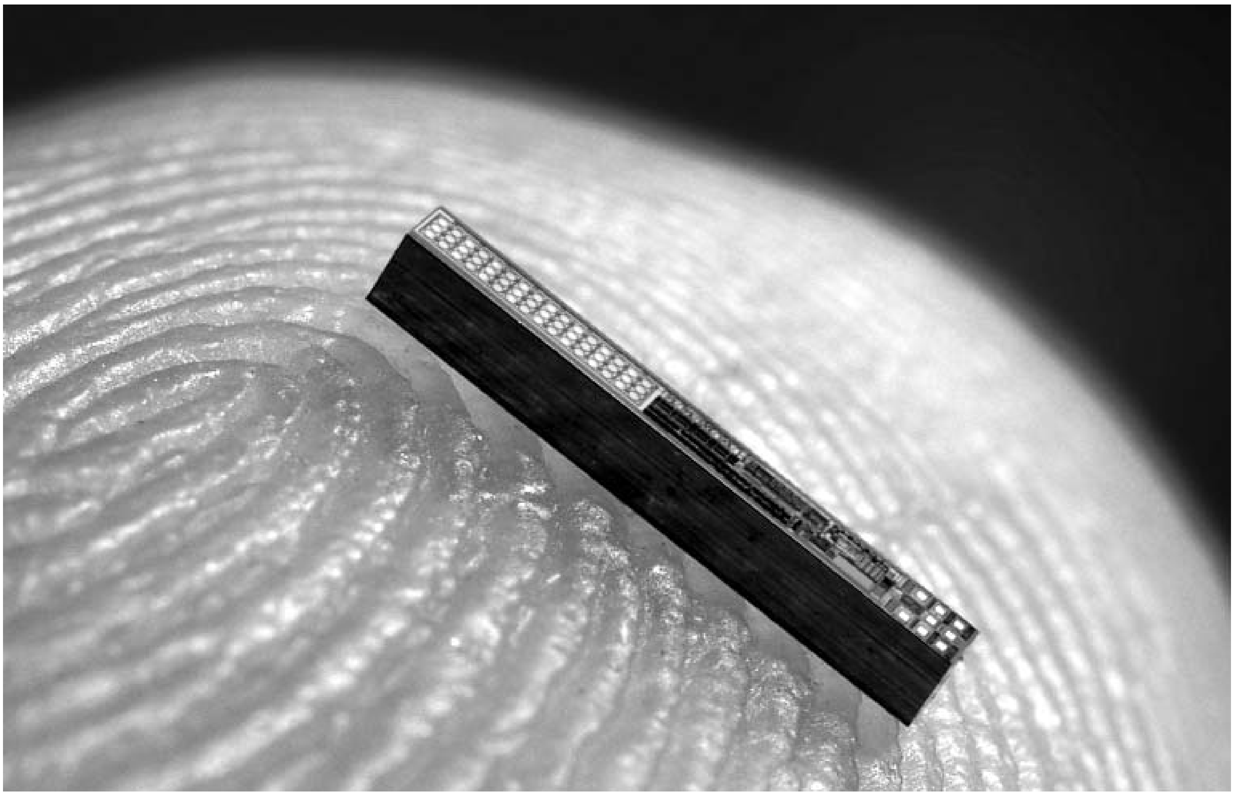

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The tiny pressure sensor – depicted here on a finger – measures blood pressure directly in the femoral artery.

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Topic 4

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Sensor in artery measures blood pressure

If a person's blood flows through their arteries at too high a pressure, even when they are lying still on the sofa, they could be in danger. High blood pressure causes the heart to constantly pump at full speed, which strains both the heart and vessel walls. Drugs can provide relief, but in many cases the patient's blood pressure is still difficult to regulate and has to be consistently monitored over a long period of time. This is a tedious process: Patients have to wear a small case containing the blood pressure meter close to their body. An inflatable sleeve on their arm records their blood pressure values, for which it is regularly pumped up and deflated. This is a burden on the patients, particularly at night. The whole process is now due to become easier thanks to a tiny implant that could replace the current method. It is being developed by Fraunhofer researchers together with the company Dr. Osypka GmbH and other partners in a BMBF-funded project called "Hyper-IMS" (Intravascular Monitoring System for Hypertension Patients).

"A doctor introduces the pressure sensor directly into the femoral artery in the groin," explains head of department Dr. Hoc Khiem Trieu of the Fraunhofer Institute for Microelectronic Circuits and Systems IMS in Duisburg. "The sensor, which has a diameter of about one millimeter including its casing, measures the patient's blood pressure 30 times per second. It is connected via a flexible micro-cable to a transponder unit, which is likewise implanted in the groin under the skin. This unit digitizes and encodes the data coming from the microsensor and transmits them to an external reading device that patients can wear like a cell phone on their belt. From there, the readings can be forwarded to a monitoring station and analyzed by the doctor." Because the researchers use special components in CMOS technology, the system requires little energy. The micro-implants can be supplied with electricity wirelessly via coils.

Implantable pressure sensors are also suitable for other applications, such as monitoring patients suffering from cardiac insufficiency. The researchers are currently performing the first clinical trials.

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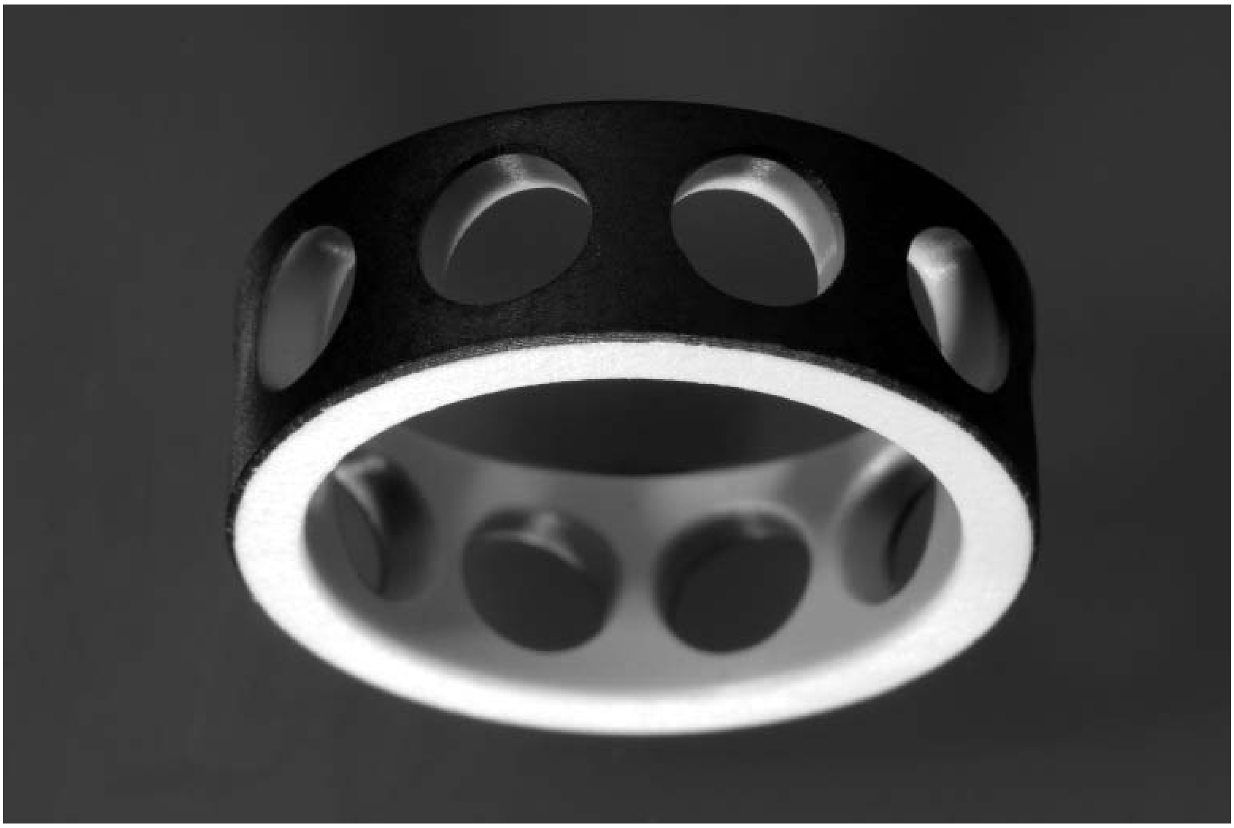

Plastic cage coated with diamond-like carbon: Bearings achieve much higher engine speeds with parts coated in this way.

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

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Precious coatings for plastic parts

Be they ball bearings in bicycles, slide bearings in the crankshafts of ships, or high-performance bearings in motor sports – bearings fulfill a wide range of functions. In many cases, they have to withstand enormous engine speeds and thermal loads, which places extremely high demands on the material from which the bearings and the associated bearing cages are made.

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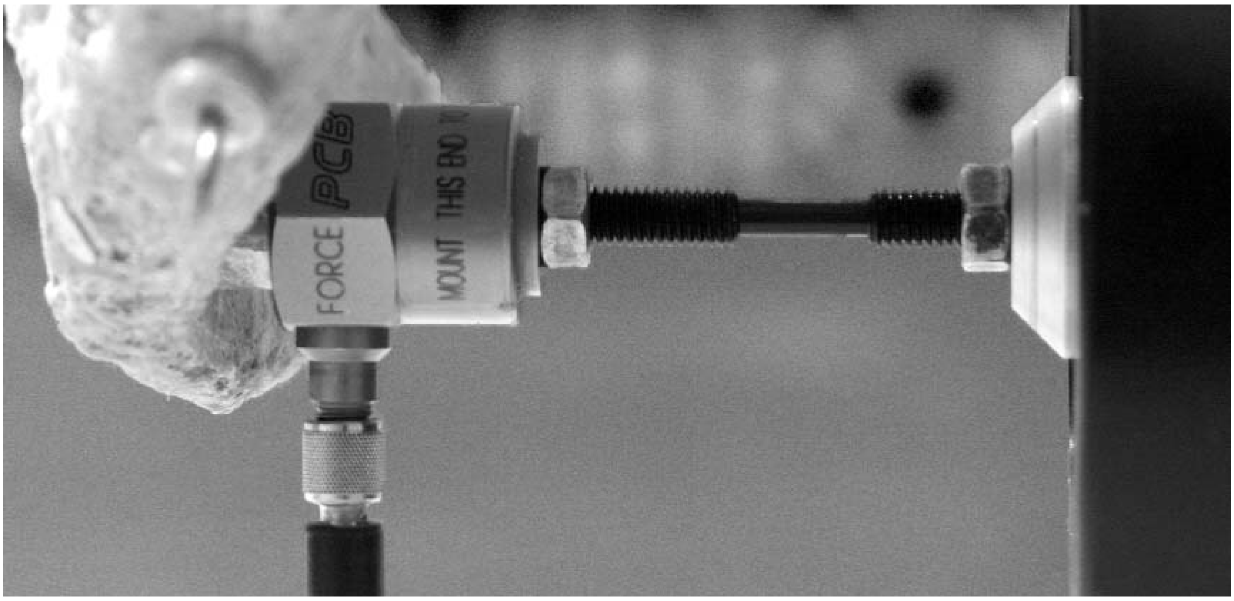
Research scientists at the Fraunhofer Institute for Mechanics of Materials IWM in Freiburg are working on the bearings of the future. They are equipping them with a very special coating that makes high-performance roller bearings, for example, even more durable and reliable than they already are. The coating consists of diamond-like carbon (DLC). "Thanks to this coating, we can produce components that are much more robust than conventional elements, such as those made of uncoated plastic," says IWM division director Dr. Sven Meier. "The coated bearings remain sturdy even if they are not sufficiently lubricated or if they run dry."

Applying the DLC coatings to the parts requires a special process developed by the scientists at the IWM. "Our coating method is also suitable for geometrically complex parts, such as bearing cages," Meier explains. The engineers have optimized the technique in such a way that even very thick DLC coatings – thicker than 20 micrometers – can be applied. "Our process enables us to generate targeted micro-structured coating systems, which in turn makes it possible to optimize the effect of lubricants and minimize friction and wear in the bearings. If required, we can also produce ultra-smooth surfaces." The researchers achieved the best coating results on components made of special plastic. Bearings made of this material achieve much higher engine speeds, develop less heat, and reach a much better service performance with the new coating than in uncoated form.

At present, the researchers are working on methods of developing coating processes specifically optimized for particular applications with the help of mathematical models. Their aim is to reduce the high costs currently required to develop such complex processes.



A shaker induces oscillations in the clamped bone (left).

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

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Topic 6

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Safely fixed hip prostheses

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Hip prostheses do not hold forever. If an implant comes loose, the doctors have to replace it. Most patients need this second operation after about 15 years. By then, the first prosthesis has often worn down the pelvic bone in several places. Moreover, the bone density, and thus also its strength, changes with increasing age. Medics therefore have to work out where best to place the screws that connect the artificial joint to the bone, and what shape the hip prosthesis needs to be in order to fit the surrounding bones as well as possible. At present, doctors examine patients using computer tomography (CT), and determine the rough density of the bones from the images. On the basis of various assumptions, they then calculate how strong the bones are in different places. The problem is that, although there are various theories on which the simulations can be based, the results often deviate significantly from reality. The consistency of the damaged bones is usually different from what the simulation leads to believe.

This is set to be changed by researchers at the Fraunhofer Institute for Machine Tools and Forming Technology IWU in Dresden and their colleagues at the biomechanics laboratory of the University of Leipzig. They are developing a model with which doctors can reliably and realistically calculate the density and elasticity of the bone from the CT scanner images. To this end, the researchers are transferring methods usually used for component testing to human hip bones, which involve inducing oscillations in the bone. This type of examination cannot be carried out on the patient. The bone has to be clamped into an apparatus. "The nature of the oscillations enables us to deduce local properties of the bone – such as its density and elasticity," explains IWU group manager Martin Quickert. The researchers compare these results with scanned images of the bone and describe the correlations on the basis of a mathematical model. This should make it possible in future to determine the strength of a bone directly from the CT scanner images. The scientists have already performed the first examinations on prepared and thus preserved bones, and plan to induce oscillations in unprepared bones left in their natural state over the coming months. The researchers hope that in about two years' time, doctors will be able to obtain a realistic simulation model of unprecedented quality from computer tomography data. The prostheses can then be perfectly anchored, and will be held safely in place for longer.

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Hybrid foams and lightweight constructions

Mother nature is a smart builder. The cell structure of bones and honeycombs, for example, is particularly resilient and gets by with extremely little material. The process by which these lightweight structures form is just as suitable for foaming metals, plastics and ceramics. These foams have specific properties depending on the material they are made of. While plastic foams are light and flexible but cannot withstand high temperatures, metal foams are extremely tough but are heavy and not very flexible. Ceramic foams are quite stiff and can resist even very high temperatures, but are rather difficult to shape.

In the automotive and aerospace industries, it would be more effective and resource-saving to combine the flexibility of plastic with the resilience of metal to create a material with entirely new properties. This is exactly what the Fraunhofer researchers are striving to do by developing hybrid foams. What is special about these materials is that they have the potential to acquire completely new characteristics, while at the same time eliminating the specific weaknesses of each constituent, such as the heavy weight of the metal foam.

The efficiency of the novel materials is to be demonstrated in three test applications: One is to increase the sound insulation in a combustion engine, another is to improve the energy absorption in a crash box, and the third is to manufacture lightweight, high-strength components. A research group comprising the Fraunhofer Institutes for Chemical Technology ICT, Manufacturing Engineering and Applied Materials Research IFAM, Ceramic Technologies and Systems IKTS, Silicate Research ISC and Mechanics of Materials IWM has taken up the challenge of developing the multifunctional hybrid foams.

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