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Research News

No. 8 – 2009

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1 Self-healing surfaces

The engineers' dream of self-healing surfaces has taken another step towards becoming reality – researchers have produced a electroplated layer that contains tiny nanometer-sized capsules. If the layer is damaged, the capsules release fluid and repair the scratch.

2 Ripe pineapple and delicious pork

Customers want fresh food, which is neither unripe nor spoilt. A new system based on metal oxide sensors could check the safety and quality of foods reliably, quickly and economically – such as how ripe that pineapple really is.

3 The perfect cut

You need the right tool to slice silicon blocks into paper-thin wafers: a several-kilometer-long wire wetted with a type of grinding paste. And all the parameters must be optimally adjusted – only then can significant material losses be avoided during the cutting process.

4 Configure your own operating software

Remote maintenance systems that monitor the status of facilities and machines have always had to be configured manually, a laborious task. But now a new system can be easily adapted for a range of facilities with no need for programming expertise.

5 Vehicle pools for goods

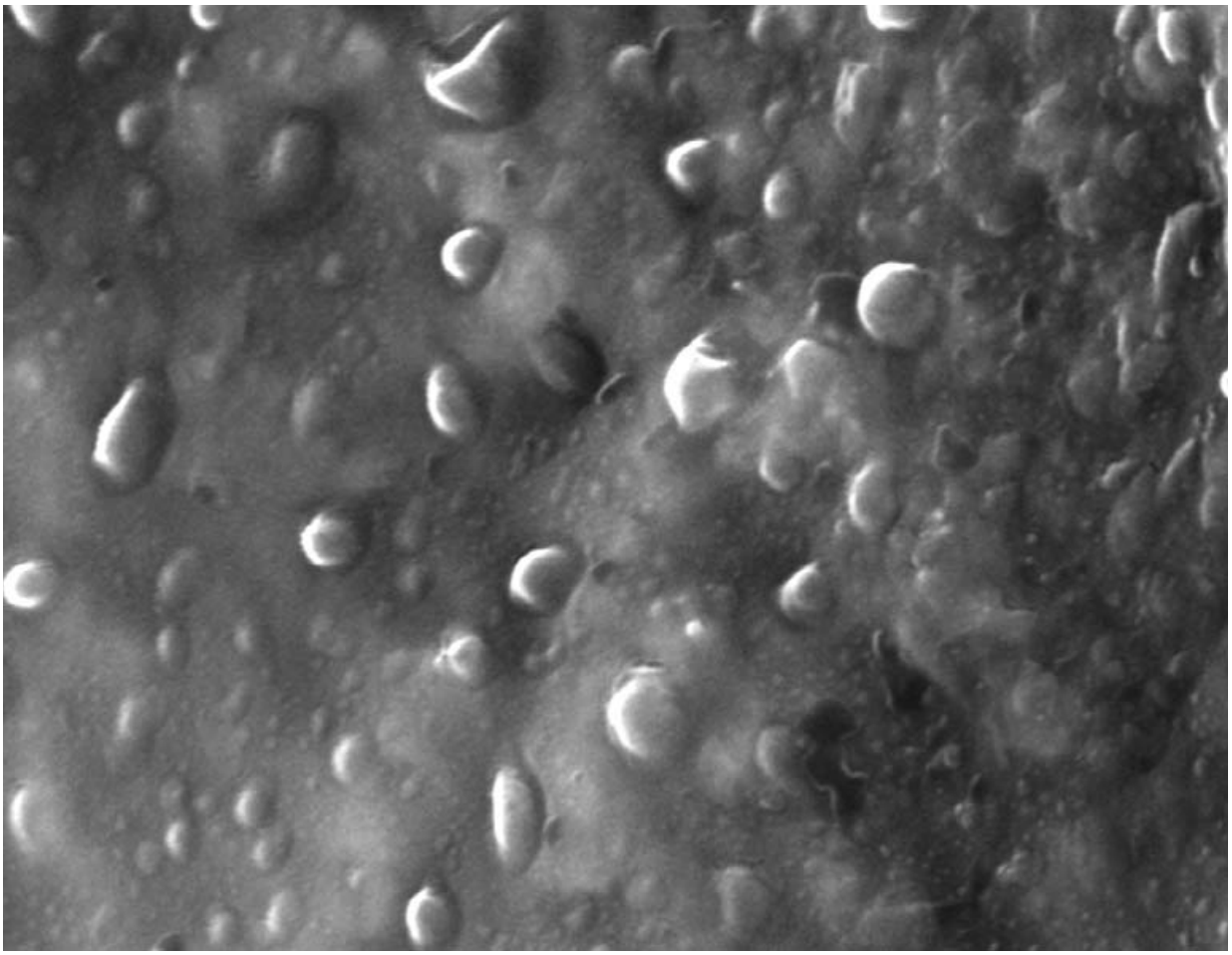
Web 2.0 can help companies located in the same region share haulage space when transporting consignments. Pooling benefits the environment, reduces CO_2 output and saves costs – experts put the figure at around 15 percent.

6 Energy efficient sewage plants

High-rate digestion with microfiltration is state-of-the-art in large sewage plants. It effectively removes accumulated sludge and produces biogas to generate energy. A study now reveals that even small plants can benefit from this process.

7 Super-sized tiny proteins

What are the causes of illness? How can the effect of medication be improved? Molecular biologists can now gain new insights by the virtual simulations generated with a new type of software.



The nano-capsules in the electroplated layer contain a fluid. If the layer is scratched, the layers burst, the fluid escapes and repairs the scratch.

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Topic 1

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Self-healing surfaces

Human skin is a phenomenon – small scratches and cuts heal quickly, leaving no trace of a scar after just a few days. It's a different matter with materials, such as metals – if the electroplated layer protecting the metals from corrosion is scratched, rust protection is lost. Engineers are working on transferring the self-healing effect of skin to materials. The idea behind this is to introduce evenly distributed fluid-filled capsules into the electroplated layer – rather like raisins in a cake. If the layer is damaged, the pellets at the point of damage burst, the fluid runs out and 'repairs' the scratch. Until now, these plans have failed due to the size of the capsules – at 10 to 15 micrometers they were too large for the electroplated layer, which is around 20 micrometers thick. The capsules altered the mechanical properties of the layer.

Researchers from the Fraunhofer Institute for Manufacturing Engineering and Automation IPA in Stuttgart, together with colleagues from Duisburg-Essen University, have developed a process for producing electroplated layers with nano-capsules, in a project being financed by the Volkswagen Foundation. At only a few hundred nanometers in diameter, the capsules are measured on another scale entirely, compared with previous results. "The challenge lies in not damaging the capsules when producing the electroplated layer", says Dr. Martin Metzner, Head of Department at IPA. "The smaller the capsules, the thinner and more sensitive their casing. The electrolytes used for these electroplated-technical processes are extremely aggressive chemically and can easily destroy the capsules". The researchers therefore had to find a compatible material for the capsule casing depending on the electrolytes used.

Mechanical bearings are one example of possible applications – the materials of the bearings usually have a electroplated coating, in which the capsules can be embedded. If there is a temporary shortage of lubricant, part of the bearing's coating is lost, the capsules at the top of the layer burst and release lubricant. The bearing is not therefore damaged if it temporarily runs dry. The researchers have produced the first copper, nickel and zinc coatings with the new capsules, although surface coverage does not extend beyond the centimeter scale. Experts estimate that it will be another one and a half to two years before whole components can be coated. In a further step the team worked on more complex systems – involving differently filled capsules, for example, whose fluids react with one another like a two component adhesive.

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Metal oxide sensor detects transient compounds.

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Topic 2

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Ripe pineapple and delicious pork

When buying a pineapple, the customer often stands helplessly in front of the supermarket shelf – which one is already ripe? If the fruit is eaten immediately it's often still not sweet enough, if it's left too long it has rotten patches. Laboratory tests are too slow and too costly to provide the answers.

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Major suppliers might soon be able to call on the help of a novel system that uses volatile components to detect when the pineapple is ripe and when it can be delivered to the supermarket. The system has been developed by researchers at the Fraunhofer Institutes for Molecular Biology and Applied Ecology IME in Schmallenberg and for Physical Measurement Techniques IPM in Freiburg. It checks gas emissions on-line – directly in the warehouse for instance. "We have brought together various technologies based on the use of metal oxide sensors, similar to those installed in cars, for example, to close ventilation vents when driving through a tunnel. Researchers at IPM have developed these sensors further. If a gas flows over the sensor, at temperatures of 300 to 400°C, it will burn at the point of contact. The subsequent exchange of electrons changes the electrical conductivity," explains Dr. Mark Bücking, Head of Department at IME. "Before the gas reaches these sensors, it has to go through a separation column with polymers. Certain substances are already filtered out here." A prototype of the analysis equipment already exists. Initial tests were promising – the system measures the volatile substances just as sensitively as conventional equipment used in food laboratories. In a further step the researchers want to optimize the system and adapt it to specific problems. Bücking reckons that the equipment could come onto the market at a four-digit euro price.

The researchers are also investigating whether the equipment could be used to test pork. The male pig produces hormones and certain odorous substances necessary for reproduction. What the female pig finds attractive, however, smells anything but pleasant to human noses. It's true that most pigs are slaughtered well before sexual maturity – before any odorous substances have formed in the majority of pigs. As there is the risk, however, that some boars could produce odorous substances prematurely, all boars are castrated when they are young piglets. Castration may not be necessary in the future if the pork could be tested on-line before it is packaged.

Using a light microscope to study sawed silicon wafer surfaces. In the foreground: a silicon block with sawed wafers, coils of wire and a finished solar cell.

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The perfect cut

The ability to cut onions into thin slices isn't just a matter of practice – choosing the right implement also helps make good onion rings. The same principle applies when cutting silicon blocks to make wafers for solar cells. You need a special slicing tool to produce paper-thin wafers from silicon blocks ("ingots"): reminiscent of an egg slicer, a filigree wire is used to cut through the ingot at a speed of up to 60 km/h. This wire is several hundred kilometers long and arranged in such a way that the ingot is sliced into hundreds of wafers simultaneously. The process takes around six hours and the resultant slices are approximately 180 µm thick.

Dr. Rainer Kübler, business unit manager at the Fraunhofer Institute for Mechanics of Materials IWM, explains: "When slicing the wafers, the challenge is to reduce the saw gap width." The space between two wafers is governed by the thickness of the wire. The steel wire is wetted with a type of paste ("slurry"), a mixture of silicon carbide and polyethylene glycol. This is harder than silicon and cuts through the ingot. The gap arises where the silicon is reduced to powder during cutting. "Gap widths are currently around 180 µm," says Kübler, "which means that given a wafer thickness of 180 µm, we generate the same amount of waste for each silicon slice. That's inefficient." The researchers "want to achieve smaller saw gap widths of around 100 µm, which are also suitable for industrial applications." In a project funded by the federal ministry for the environment (BMU), they are currently studying the abrasion process and contact regimes using a single-wire saw and are principally interested in the interactions bet-ween the wire, the slurry and the silicon. They are also using computer modeling to simulate different configurations. What forces are at work when sawing with thin wires? How can one ensure the wire is well wetted? What is the best grain size for the slurry and how must the particles be distributed?

"We want to answer all these questions and ultimately arrive at optimal wire and slurry systems that are suitable for industrial applications," says Kübler. The researchers are currently striving to achieve gap widths of 90 µm, which would represent a huge increase in efficiency as waste would be halved.

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Research News
Topic 4

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Configure your own operating software

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Is the oil pressure in the hydraulic system too high? What's the current condition of the rotor blades on that wind turbine plant? It is important for the people who operate facilities and machines to be able to answer this sort of question at any given time, because malfunctions and failures can prove to be costly. Condition monitoring systems, or CM systems, are used to monitor machines remotely: sensors mounted on the equipment feed continuous measurements back to a control box, which records and stores the data, and if an error occurs, the system alerts the operator. However, before a CM system goes live, it has to be adapted for use with the specific facility it is to monitor. This requires laborious manual programming work which can often cost in excess of 100,000 euros.

Things may prove a lot simpler and less costly in the future, however. Researchers at the Fraunhofer Institute for Experimental Software Engineering IESE in Kaiserslautern have developed a CM system for Lösi GmbH which can be adapted for use with various types of facility without the need for manual programming. "We've developed our own configuration language that is specially tailored to CM systems," explains project leader Dr. Mario Trapp. "You don't need any programming expertise to work with the language – it's a straightforward process for the engineer to set up the operating software using the 'drag and drop' function." The user sees the available tools in icon form on the screen, clicks on the ones he wants and simply drags them to where he wants them. For example, if he wants to include a pressure sensor in the operating software, he selects the appropriate icon and sets pressure threshold values. An Options menu allows him to control how the system should react if these values are exceeded. Depending on how serious the error is, the control box can load deviating measurements into a central database, or else inform the facility operator via SMS. Emergency shutdown of the facility is a further option that can be configured. Once everything has been set up, a code generator automatically programs the corresponding control box. "Our CM system is every bit as powerful as solutions which require manual programming, but it's significantly more cost-effective. Clients can potentially make five-figure savings," says Trapp. Even after it has gone live, the CM software can be altered at any time, for example to add new sensors. With conventional systems, by contrast, the client would have to bring the manufacturer back in to do this. Several clients are already trialing prototypes of the software.

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Topic 5

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Vehicle pools for goods

"Have you got a spare seat on the journey to Berlin?" Many weekend commuters use opportunities to travel together, instead of driving alone. It's more companionable and saves petrol, money and CO_2. Something similar could also become reality for goods consignments from companies located close to one another: pooling of transport on rail and road reduces the environmental burden and saves costs – experts put the figure at around 15 percent.

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"It has hardly been possible until now to get an overall picture of the combined road-rail transport options available for sending individual consignments. The systems presently in use do not make specific proposals for joint haulage," says Agnes Eiband, Project Manager for freight transport at the Fraunhofer Institute for Material Flows and Logistics IML in Prien. "Companies must themselves locate the goods transfer terminal nearest to them – and to their customer at the other end. They then need to find out what the connections are like, how much train transport will cost, and how to organize delivery and collection of the goods". Far too complicated for many companies, that end up sending their consignments to customers by truck, as usual – also because they do not always have enough goods to fully load a train.

Experts from the IML's Prien Project Centre, have developed a new web-based tool with colleagues from the Fraunhofer Institute for Production Engineering and Automation IPA in Stuttgart: Intermodal4all. With a click of the mouse this tool finds out the options available to local companies who want to transport their goods jointly and economically. This prototype system suggests the most suitable shared-haulage partner company and displays a map of the route the consignment will take. The 'rail configurator' calculates the different rail and road variants, while another module evaluates the options and optimizes haulage enquiries. "Local companies can either use already existing train connections or jointly set up a train service, which might cover a longer distance once a week," explains Eiband. "Service-orientated software architectures and web services ensure that customers can actively use Intermodal4all throughout Europe. The modular configuration ensures that other transport optimization systems are integrated and can continue to be used." That also makes the software solution attractive to trucking companies or major transport users who want to optimize their haulage services.

Sewage plant in Schwerzen. This 10, 000-strong municipality has already opted for high-rate digestion.

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Topic 6

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Energy efficient sewage plants

Sewage plants remove organic matter from wastewater. If the accumulating sludge decays, biogas is generated as a by-product. However, only 1156 of the 10,200 sewage plants in Germany have a digestion tank. Smaller operations, especially, baulk at the costs of a new digestion tank. Instead, they enrich the sludge with oxygen in the existing activation basin, and stabilize it. "Activation basins require a lot of electricity. At the same time, enormous energy potential is lost, since no biogas is produced," says Dr. Brigitte Kempter-Regel of the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB in Stuttgart. "A sewage plant eats up more electricity in the municipalities than their hospitals do".

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In a cost-benefit-study Dr. Kempter-Regel has shown that it also pays small sewage plants to transfer to more energy-efficient processes – even if they have to invest in a sludge digestion unit. "Based on a sewage plant for 28,000 inhabitants, we calculate that the plant can reduce its annual waste management costs from 225,000 euros by as much as 170,000 euros if sludge is decayed in a high-rate digestion unit with microfiltration, as opposed to treating it aerobically", she says.

This process was developed at IGB and is much more effective than conventional digestion. Instead of the usual 30 to 50 days, sludge only remains in the tower for five to seven days. Around 60 percent of the organic matter is converted into biogas – the spoil is approximately a third more than in the traditional digestion process. The biogas obtained can be used to operate the plant, which, in the case study, would cut energy costs by at least 70,000 euros each year. High-rate digestion has the added advantage of producing less residual sludge needing disposal. "This saves the operator another 100,000 euros", says Kempter-Regel. In addition to high energy prices, budgets are also being hit hard by increasing waste management costs. The use of residual sludge in agriculture is controversial, and slurry can no longer be disposed of on landfills; burning the sludge is a very expensive alternative. So an effective reduction of sludge through digestion pays off. Even small sewage plants have already followed the recommendation of the Stuttgart Institute and converted to the high-rate digestion process.

At the press of a button "BioBrowser" provides high-quality, interactive displays of molecules.

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

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Super-sized tiny proteins

If it's a question of the efficacy of vaccines or the aggressiveness of toxins, researchers must be able to simulate and analyze the molecules involved in three dimensions. What do they look like? What is the three-dimensional structure of a protein? How can this structure be used to predict which molecules the protein interacts with? What function does it have? In the software applications most widely used today, the depiction of the simulated protein and the quality of the graphics leave a great deal to be desired – especially if larger molecules, consisting of thousands of atoms, have to be visualized and examined.

This is likely to get a lot easier with the arrival of "BioBrowser" a software application developed as part of a German Research Foundation project by researchers specialized in Visual Computing at Fraunhofer Austria in Graz. Based on research data of molecular biologists, the software automatically calculates and displays 3D models of complex proteins – at the push of a button, in high quality, and interactively. Researchers can turn the molecule and look at it from every angle, enlarge it at will and select specific areas; the image is always razor sharp and users can switch between the most important variants. Visualized models can be very large and complicated – they often consist of 50,000 and more atoms. "When examining molecules, an enormous flood of data is generated that in itself makes little sense at all. BioBrowser converts this data into graphic images and makes the links between different molecules visible", summarizes Dr. Eva Eggeling, Head of Visual Computing.

Interested researchers receive a download link on request that gives them direct free-of-charge access to the program. They can also arrange an appointment with colleagues in Graz to study the proteins on a large 3D projection screen. The Graz researchers are hoping this will give new drive to molecular biology and the development of medicines. At the moment they are working on extending and improving the user interface. Feedback from the first scientific users helps the Graz researchers decide whether they need to add other functions. The product is primarily directed at Austrian scientists, but can also be used worldwide. "We are also reckoning on enquires from other European countries, particularly from Germany and Switzerland", explains Eggeling.

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