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Research News

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1 Sensitive robots

Robots are commonplace in production halls, but are only allowed to operate in protected areas so as not to endanger humans with their movements. A new cost-efficient, robust force sensor can make robots sensitive to potential collisions.

2 Sensitive fitting process for leg prostheses

Leg prostheses need to be optimally adapted so that patients can walk properly. Until now, medical staff have had to document one or two steps by the patient in a gait laboratory. A new prosthesis adapter now records the wearer's steps for a whole day – outside the lab.

3 Keeping the heat down

Electronic products are having to accommodate more and more components, all of which generate heat. Too much heat could put laptops and other devices out of action, so manufacturers equip them with metal plates to discharge it. A new composite can do this better.

4 Electrosmog on the circuit board

The smaller the components in electronic circuits, the more interference-prone they are. If the components are too densely packed, they can interfere with one another. A near-field scanner can accurately detect weak fields and help to protect bank cards against fraud.

5 Timely maintenance guaranteed

On construction sites, machines several meters large ram heavy steel planks and girders into the ground by generating targeted vibrations. In future, a new electronics system will monitor the expensive tools, indicate when they need servicing and thus prolong their useful life.

6 Data mining improves production quality

Why is it that one machine component wears out so quickly when others last for ages? The PRODAMI tool provides a targeted diagnosis of faults that occur in production plant, enabling component and other failures to be detected and corrected in advance.

7 Beautifully varnished – using renewable

How do you make a scratch-resistant varnish using sugars and vegetable oils? Researchers can show how it's done: They have developed a furniture varnish containing roughly 50% renewable raw materials that offers the same hard-wearing quality as conventional varnishes.

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A force sensor (square at the center) ensures that robots instantaneously sense collisions. The sensor is attached to a steel plate and can be screwed onto the outer joint of the robot arm.

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Topic 1

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Sensitive robots

The arm of the industrial robot steadily approaches the employee, who is so absorbed in his work that he doesn't notice – a risky situation. But as soon as the robot even slightly touches the person, it immediately retracts its steel arm. This vision could soon become reality thanks to a cost-efficient force and torque sensor developed by research scientists at the Fraunhofer Institute for Silicon Technology ISIT in Itzehoe. The sensor sits on the outer joint of the robot's arm. Glued onto a steel plate, the transducer, it can be screwed in between the arm and the grabber. "We expect our sensors to be far cheaper than conventional force sensors once they enter mass production. This makes them suitable for wide-scale use," says ISIT head of department Jörg Eichholz. Equipped with the new sensors, robotic assistants would be sufficiently trustworthy to work alongside their human colleagues – something that has been prohibited until now for safety reasons.

The sensor measures the forces and torques exerted by the robot arm. "It functions in a similar way to a strain gauge: its core element is a long wire through which an electric current flows. If the wire stretches, it becomes longer and thinner – the resistance increases and so less current flows through it," says Eichholz. "Our sensor is made from a single square piece of silicon. On each side, we have incorporated bridges carrying electrical resistances." If the robot arm bumps into an obstacle, the shape of the silicon changes very slightly – by just a few micrometers, to be precise. This causes either more or less current to flow, depending on whether a bridge has been stretched or buckled. Because the sensor consists of just a single piece of silicon, it is less error-prone than its conventional counterparts. Manufacturers normally glue the resistances on separately, which means they are often positioned somewhat inaccurately. "There is no chance of this happening in the case of our sensor. The resistances are precisely aligned," says the expert. The system's size can be varied.

The sensor can also help to program a robot. In learning mode, it measures the force with which the employee guides the robot arm. Instead of laboriously entering the coordinates of the movements into the computer, the employee can simply guide the robot by touch and teach it the required motion sequences in this way. The researchers will present a prototype of the sensor at the Sensor + Test trade fair (Hall 12, Stand 688) in Nuremberg from May 26 to 28.

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A new adapter makes it possible to continuously measure the load on a leg prosthesis during different routine activities.

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Topic 2

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Sensitive fitting process for leg prostheses

Is the prosthesis suitably adjusted? Are the foot and the knee joint working together as they should? How harmonious is the patient's gait? All these questions can be answered in a gait laboratory. Special plates in the floor of the lab measure how forcefully patients place their feet when walking and how they roll them. The movements are also recorded by several cameras. This helps the orthopedic technician to perfectly adjust the prosthesis. However, the measured data only take into account one or two steps made by the patient and repeated several times.

In future, it will be possible to optimize prostheses outside the gait lab, too, and with greater accuracy. Researchers at the Fraunhofer Institute for Surface Engineering and Thin Films IST in Braunschweig have developed a special adaptive sensor in collaboration with Otto Bock HealthCare GmbH. The adapter measures 4 x 4 x 3 centimeters and sits at the ankle joint or above the knee. It measure the applied forces in three spatial dimensions and three torque moments. A miniature data logger near the sensor reads out the data and stores them. "This adapter makes it possible to continuously measure the load on a leg prosthesis during different routine activities throughout an entire day," says IST team leader Dr. Ralf Bandorf. The adapter has eight measuring bridges, each with four strain gauges. These consist of a sputtered insulating layer covered with a metal film. When the patient walks, the layer stretches according to the type of movement performed, and this changes the electrical resistance of the metal film. The 32 strain gauges are placed at a number of different points and in different orientations, so the data provide a complete picture of the load acting on the prosthesis. Strain gauges used in sensor systems normally consist of adhesive films, but in this case the layers are sputtered directly onto the surface. This means they can also be applied to the complex geometries of the adapter, for instance its edges, which would be difficult in the case of adhesive films. Moreover, the film is insensitive to moisture and does not require the use of adhesives.

"The main challenge was to design a suitable geometry for the adapter," says Dr. Ralf Bandorf. It mustn't be too large, as there is only limited space available inside the prosthesis, but it has to be large enough to accommodate the strain gauges. The developers are already testing a prototype of the adapter on the first patients, and will present it at the Hannover Messe (Hall 6, Stand F48) from April 20 to 24.

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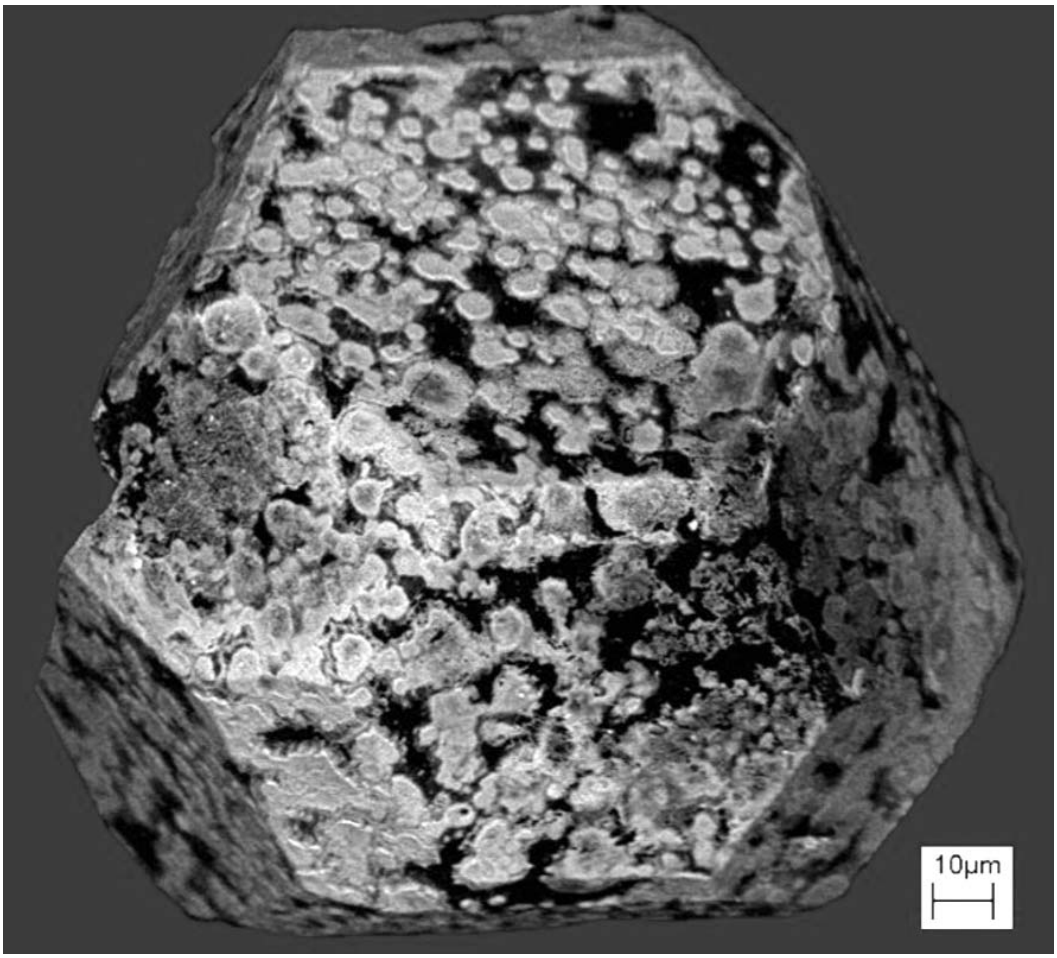

Diamond crystal with a carbide film (white)

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Topic 3

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Keeping the heat down

While portable computers were still rather cumbersome several years ago, they now easily fit inside small briefcases. This is because the components on the substrates and microchips are shrinking in size with each successive model. They are also spaced closer together, allowing more circuits to be accommodated on each chip. All of these components generate radiant heat, much like small power plants. The more components are packed into a limited space, the more difficult it is to dissipate the heat. And too much heat could put the electronics out of action. The components and connecting elements can only withstand temperatures of 90 to 130 degrees Celsius. Manufacturers therefore mount a small copper or aluminum plate underneath them to conduct the heat away. The plate, in turn, is soldered to ceramic components or silicon (the main constituent of the chip). If this system heats up, the metal plate expands about three or four times as much as the silicon or the ceramics. This causes tension which can lead to cracks in the soldered joints, so there are limits to how far components can be miniaturized.

Industrial users are calling for a material with special properties that can efficiently dissipate heat even in devices with densely packed components and that can give increasingly miniaturized electronics a longer life. The material needs to be able to conduct heat even better than the aluminum or copper materials used so far, but should not expand to a greater extent than ceramics or silicon at high temperatures. Such a material has now been developed by researchers at the Fraunhofer Institute for Manufacturing Engineering and Applied Materials Research IFAM in Dresden together with industrial partners including Siemens and Plansee as part of the EU project "ExtreMat". The researchers have even surpassed the already relatively high thermal conductivity of copper: "We did this by adding diamond powder to the copper. Diamond conducts heat roughly five times better than copper," says IFAM project manager Dr. Thomas Schubert. "The resulting material expands no more than ceramics when heated, but has a conductivity one-and-a-half times superior to copper. This is a unique combination of properties." However, it isn't easy to unite copper and diamond. The researchers had to find a third ingredient to chemically bond the two materials. "One ingredient we can use to achieve this is chrome. Even small amounts form a carbide film on the diamond surface, and this film easily bonds to copper," Schubert explains. First demonstrators of the material have already been produced.

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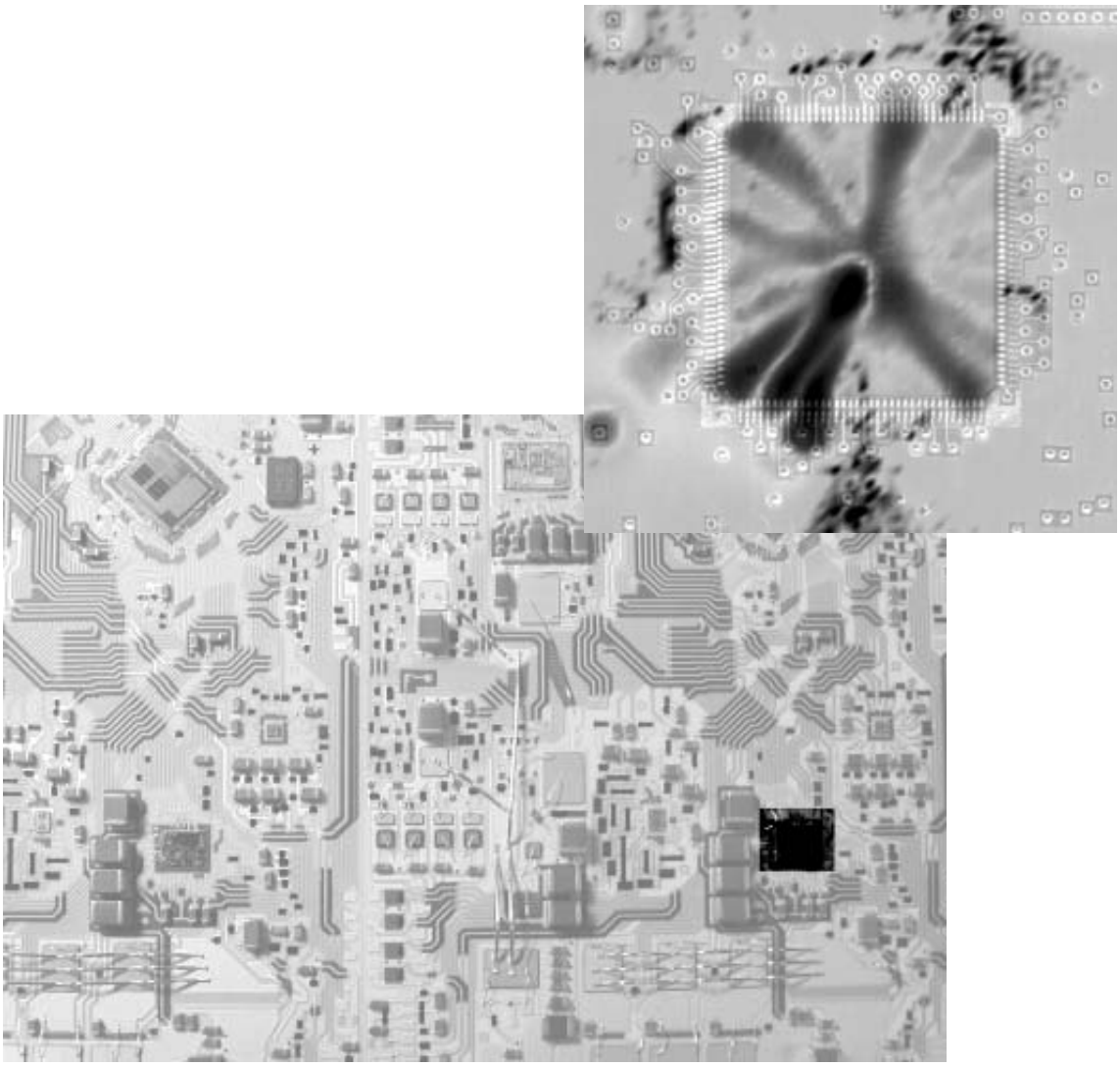

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The components on the circuit board of a car control unit are densely packed (bottom). A near-field scanner can determine the electromagnetic field of any chip on the board (top).

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Electrosmog on the circuit board

Their miniature size is their strength – and also their weakness. Be it in cell phones, cars or computers, electronic components are getting smaller and smaller and increasingly powerful. The smaller they are, the faster they can switch and the less energy they need for each switching operation. However, as energy requirements shrink, so do signal-to-noise ratios. "Circuits are becoming more and more susceptible with each generation," explains Thomas Mager of the Fraunhofer Research Institution for Electronic Nano Systems ENAS in Paderborn. "Only a few years ago, it still took several volts to destabilize processors. Today, a few hundred millivolts are sometimes enough to disrupt millions of transistors." This means that designers of electronic circuits need to give greater consideration to electromagnetic compatibility. It is no longer just a question of protecting complete electronic packages such as cell phones or MP3 players against external influences, or shielding the environment against their electromagnetic emissions, but is also about how each individual component on the circuit board behaves.

In a collaborative project carried out with Continental and Infineon Technologies, the Fraunhofer ENAS has developed a measuring system that can locate even the weakest electrical and magnetic fields to an accuracy of a few hundredths of a millimeter. Where are there areas of conspicuously high electromagnetic radiation? How do the components influence one another? The near-field scanner can scan not only individual chips and processors but also complete laptops, cell phones or aircraft control units, and can reveal which types of field the test object is radiating.

"We are also working with our French project partner CEA-Leti on a function that applies targeted electromagnetic fields to the test object. In this way, we can test for areas that respond sensitively to external fields," says Mager. This makes the system particularly interesting for developers of smart cards. Fraudsters elicit confidential information from bank cards by bombarding them with pulses of laser light, electrical current or voltage. The resulting field patterns can reveal details about the chip card, such as its PIN number. The near-field scanner provides time- and space-resolved images of the radiated fields of the card, allowing their weak points to be identified and helping card developers to better protect their products against fraud.

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A machine rams a heavy steel girder into the ground. In future, a new electronic system will monitor the expensive equipment and indicate when it needs to be serviced.

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Topic 5

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Timely maintenance guaranteed

A steel plank weighing more than 300 kilograms sinks into the ground under continuous vibrations, rammed into the earth by what is known as a construction vibrator. Unbalanced masses inside the machine rotate to produce strong targeted vibrations. These are transferred to the steel plank and greatly weaken the soil – "liquefy" it, so to speak. The plank sinks on account of its own weight. Several such planks can be joined together to make building pits, for example, or steel quay walls in ports. The machines are very expensive, so small building companies usually hire them from rental firms as and when they need them.

Construction vibrators have to endure heavy loads and require regular servicing, during which a technician changes the oil and replaces the seals. The longer a machine has been in action, the more frequently it has to be serviced – much like a car, which has to be taken for an inspection after clocking up a certain mileage. However, rental companies can only make a rough estimate as to how long a machine has been in use overall with its customers, and when it needs to be serviced next. Should they fit in an extra maintenance inspection before renting it out to the next customer?

An electronic guard developed by the Fraunhofer Institute for Microelectronic Circuits and Systems IMS in Duisburg will answer this question in future. "It keeps track of how many hours the machine is in operation," explains IMS project manager Frederic Meyer. The hour counter is housed in a small box measuring five by seven centimeters, can be mounted on any construction vibrator, and oscillates at the same frequency as the machine. "At one-minute intervals, the electronics determine whether the machine is currently vibrating and, if so, at what frequency. This is done using an acceleration sensor and an internal clock," says Meyer. A technician reads out the counter via a radio link and can thus see whether he needs to service the machine before it is delivered to another customer. The electronics also monitor the temperature of the construction vibrator. This is necessary, for if the machine is over-used, it runs hot and wears out more quickly. "Temperatures of 85 degrees Celsius and above can damage the seals," Meyer explains. In future, the electronic guard will record any threateningly high temperatures that occur and will warn the technician, who can then organize an additional inspection. The researchers have already successfully tested the first prototype, and the system is currently being put through its paces by their customer, ThyssenKrupp GfT Tiefbautechnik.

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Topic 6

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Data mining improves production quality

The robot arm picks up the car door and moves it across to the body of the vehicle, where it is automatically attached to the hinges under automatic, central software control. This complex manipulation adds an element of risk to the underlying production process. The slightest programming inaccuracy can lead to production errors – such as repeated quality problems affecting a certain part of the vehicle. Such problems are not always detected immediately. "Quality problems due to the unreliability of manufacturing processes are often detected too late for their origin to be diagnosed and localized, preventing corrective or optimization measures from being introduced at the appropriate time. This is equally true at the product development and factory planning stage as during production planning on a corporate level," says Dr. Helge Björn Kuntze, department head at the Fraunhofer Institute for Information and Data Processing IITB in Karlsruhe.

He and his team of researchers have developed the PRODAMI software that enables such errors to be detected rapidly and eliminated. "Employees can use our software to monitor, plan and control manufacturing systems in real time, in any production department," says Kuntze. It is based on data mining tools, which can search through huge volumes of data in a minimum of time and identify characteristic information patterns out of a multitude of production and sensor data. The patterns provide a quick and easy way of detecting errors. Until now, the task of interpreting the flood of data delivered by sensors, numerical and process control systems was extremely time-consuming – and the data were therefore seldom utilized.

The IITB is partnered in the PRODAMI project by the Fraunhofer Institutes for Production Systems and Design Technology IPK in Berlin and for Industrial Mathematics ITWM in Kaiserlautern. Data mining methods are already being employed successfully in marketing applications, financial planning, and genetic research. But it is rare to find them in a production environment, firstly because they haven't until now provided real-time data analysis, and secondly because the data sources are too varied. PRODAMI, by contrast, can be easily integrated in different data and communication structures and analyzes the data in real time. To ensure that the PRODAMI tools can be integrated smoothly in online production processes, machine learning methods are also employed. The researchers will be presenting PRODAMI in a joint Simulation exhibit at the Hannover Messe from April 20 to 24 (Hall 17, Stand D60).

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Topic 7

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Beautifully varnished – using renewable

When the petroleum runs out, renewable sources of raw materials will have to be found to replace petrochemical feedstocks. In the case of furniture varnishes, Fraunhofer researchers at the Institute for Wood Research, Wilhelm-Klauditz-Institut WKI in Braunschweig have already developed an alternative product in which the majority of petrochemical components have been substituted. Their water-soluble furniture varnish is based on vegetable oils and sugars and has identical properties to the conventional varnishes on sale today. It is hard-wearing, scratch-proof and resistant to chemical attack.

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"This varnish offers the coatings industry an attractive alternative to petrochemical products that is economical to produce and performs well in all tests," reports Dr. Claudia Philipp of the Fraunhofer WKI. The new varnish is based on the chemical compound 1,3-propandiol, which is derived from glycerin. Glycerin in turn is the basic substance found in all vegetable oils, and is readily available as a byproduct of manufacturing processes for fatty acids and biodiesel, for example. In the laboratory synthesis, the researchers transform 1,3-propandiol into polyurethane, which serves as a binder in hard, transparent, scratch-resistant varnishes. "The aim is to use the relatively cheap 1,3-propandiol as a substitute for one of the more expensive petrochemical synthesis components, without altering the coating properties of the varnish," explains Dr. Guido Hora, department head at the Fraunhofer WKI.

1,3-propandiol has not been considered a valuable raw material in the past, and rarely enters into the composition of varnishes. "Our first step was to conduct a detailed analysis of the relationship between the starting material and the properties of the final product," Dr. Claudia Philipp relates. The outcome was that: "As the chemical structure of 1,3-propandiol led us to surmise, the new varnish is not only hard but also resilient." In other words, it doesn't chip when a cup or other object is dropped onto a varnished table. A good varnish needs to be hard, but also capable of amortizing shocks to a certain extent, so as to prevent damage to the item of furniture beneath the coating. Another advantage of the new varnish is that it contains no N-methyl-2-pyrrolidon (NMP), a solvent once widely used in polyurethane coatings. This substance is meanwhile known to have a toxic effect on the growing embryo and is classed throughout the EU as a hazardous chemical requiring a warning symbol on all products containing a concentration higher than five percent.

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