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RESEARCH NEWS

09 | 2012 ||

1 A smart fabric sets off the alarm

Researchers have developed a new kind of anti-theft system, based on a woven fabric that triggers an alarm when penetrated by intruders. The smart fabric enables the exact location of the break-in to be identified, and is significantly cheaper than other burglary detection systems. It is also suitable as an invisible means of protecting entire buildings.

2 More accurate wind energy forecasts

Wind power is one of the most important forms of renewable energy. In order to exploit inland wind as effectively as possible, turbines must be optimally positioned and dimensioned. A 200-meter high wind measuring mast delivers precise data that can also be used to forecast energy yields.

3 Wireless window sentinel

Window contacts tell users if a window is open or closed. Typically, such sensors are wire-based. Scientists working with industry partners recently developed a new system that operates without wires or batteries. It draws its power from its environment: from sunlight and ambient heat.

4 Turning ideas into products faster

Together with the specialty chemicals company LANXESS, Fraunhofer researchers have engineered and built a system in record time, which produces reverse osmosis membrane elements for water treatment. Virtual engineering allowed research and development to proceed simultaneously.

5 Manufacturing crack-resistant lightweight components

Cold cracking in high-strength steel presents major quality assurance challenges for the automotive and machine-building industries, since cracks are difficult to predict – until now. A new process can determine, as early as the design stage, if critical conditions for such damage can be prevented. This lowers development times and costs.

6 Measuring glucose without needle pricks

Pricking a finger everyday is just part of everyday life for many diabetes patients. A non-invasive measurement approach could release them from the constant pain of pin pricks. The linchpin is a biosensor engineered by Fraunhofer researchers: A tiny chip combines measurement and digital analysis – and can be radioed to a mobile device.

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 20,000, who work with an annual research budget totaling 1,8 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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A smart fabric sets off the alarm

Thieves are unlikely to appreciate this fabric, which looks innocuous but in fact incorporates a fine web of conductive threads connected to a microcontroller that detects warning signals emitted when the fabric is cut and triggers an alarm. This system can be used to protect buildings, bank vaults, and trucks against even the most wily of intruders. Vehicles parked overnight at truck stops are particularly vulnerable to attacks by thieves who slit open the canvas tarp covering the trailer while the driver is asleep and make off with the cargo. If the tarp were made from the smart fabric, the driver in the bunk would be immediately alerted.

The smart fabric was developed by researchers at the Fraunhofer Institute for Reliability and Microintegration IZM in Berlin in collaboration with the Technische Universität Berlin and ETTLIN Spinnerei und Weberei Produktions GmbH. The company in Ettlingen manufactures technical textiles, among other things, and has filed a patent for the innovative fabric. IZM project manager Erik Simon can envision a whole swathe of potential applications, particularly where there is a need to provide protection over a large surface area. "The fabric could be used to implement an entirely novel, invisible security system for buildings," he says. For example, the textile could be laid on the rafters of a roof as an additional layer to the vapor barrier underlay, underneath the tiles. This might be a good solution for museums housing valuable collections, or jeweler's shops, or banks. An alternative solution would be to integrate the fabric in concrete and blockwork walls, for instance those surrounding a bank vault. Another possibility is to use it as a backing material for floor coverings, in combination with pressure sensors that signal an alarm if an unauthorized person enters the room. "The electric current flowing through the fabric is so weak that it presents no danger to humans or animals," says Simon reassuringly.

Precise identification of the point of entry

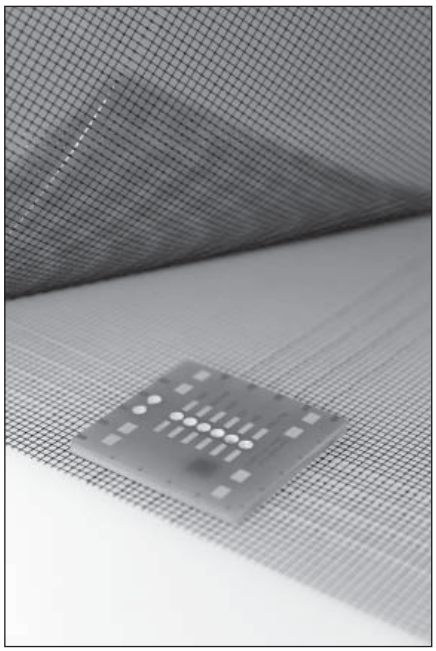
What makes this solution unique is the fact that it not only signals the presence of intruders but also indicates the precise point of forced entry. The fine lattice of conductive threads woven into the fabric enables the place where it was cut to be identified to the nearest centimeter. Other solutions currently on the market require a complex system of optical fibers, which naturally makes them more expensive.

There are also other reasons why this fabric is cheap to produce. The process makes exclusive use of standard materials and components such as silver-coated conductive threads and a simple but robust signal evaluation system. A further advantage is that "the conductive thread can be incorporated in the polyester substrate using an industry-standard textile-weaving process," explains Simon. The result is reams of fabric that can be trimmed to any length and customized to provide the desired functionality for surfaces of any size, from one square meter upward.

The conductive lattice and the data-processing module that triggers the alarm in the monitoring center are incorporated in a low-temperature process using joining techniques borrowed from the semiconductor industry such as adhesive pressure bonding and non-destructive welding. "This method has never been used before in this kind of application," says Simon, who describes the process as "simple and reliable". And this is precisely the selling point of the solution: the ability to create an entirely new product with immediately appreciable benefits using existing materials and joining techniques.

Tested from every angle

The all-important question was to determine the fabric's reliability and durability, especially with respect to the electrical contacts. To verify this, the textile alarm system was put through a grueling series of tests in the IZM laboratories. It was beaten and tumbled in a washing machine at 40 degrees Celsius, and exposed to the elements for 1,000 hours at a relative humidity of 85 percent and a temperature of 85 degrees Celsius. It was then placed in a furnace in which it was subjected to 1,000 temperature cycles ranging from minus 40 to plus 85 degrees Celsius. The smart textile stood up to this torture without flinching. Simon: "It didn't fail once."



A smart fabric incorporating conductive threads and a processor module provides protection against intrusion and theft. (© Fraunhofer IZM) | Picture in color and printing quality: www.fraunhofer.de/press

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More accurate wind energy forecasts

The decision has been taken by the German government to transform the energy system and phase out nuclear energy power. The transition process is gaining impetus but much remains to be done. During the course of which, the production of wind energy is to be dramatically expanded – not only through costly offshore facilities, but onshore as well. "There is still immense potential inland that remains to be tapped, such as in the low mountain ranges," says Tobias Klaas, scientist at the Fraunhofer Institute for Wind Energy and Energy System Technology IWES in Kassel. Klaas is also the head of the "Inland Wind Energy Use" research project sponsored by the German Federal Ministry for the Environment.

To run a wind farm as efficiently as possible, planners must know in advance precisely what wind speeds predominate at the site, and what kind of turbulence is to be expected. The problem: "With conventional methods, it is almost impossible, or possible only at great effort and expense, to measure projected power when planning modern, large-scale facilities," says Klaas. Moreover, forests and hills hamper the analysis of wind conditions. Experts refer to this aspect as "complex terrain," where topography influences wind conditions, even at great heights.

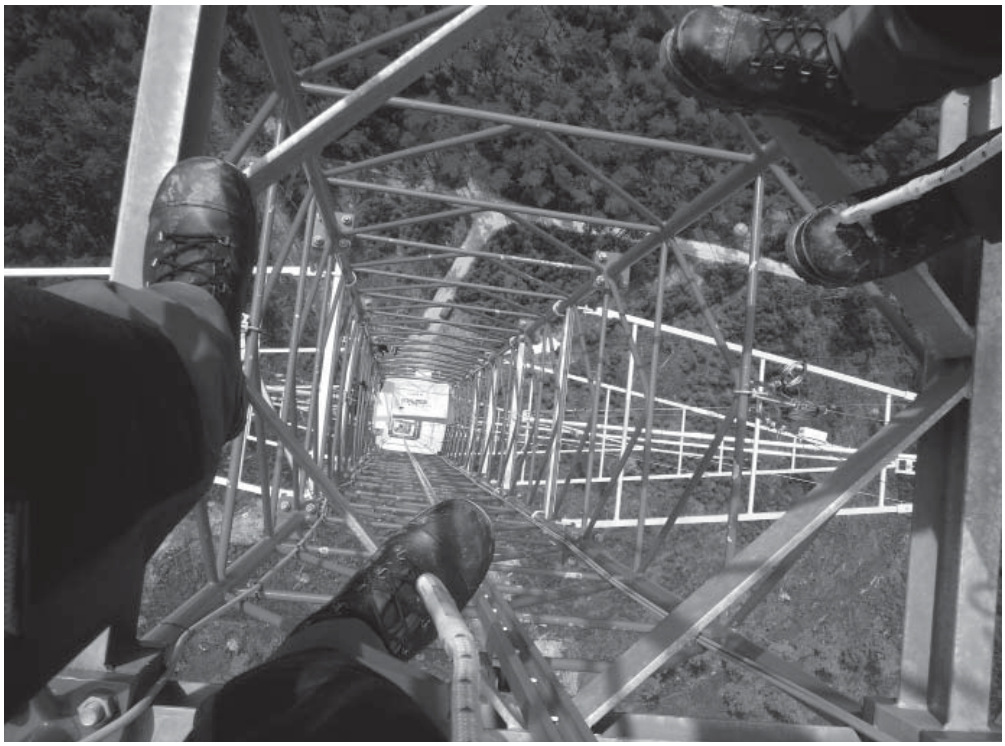
Tallest wind measuring mast in Europe

For these reasons, Klaas and his colleagues at IWES erected a 200 meter wind measuring mast. Since January, on a tree-covered hill not far from Kassel, they have been taking measurements of wind speeds, turbulence and additional meteorological data. It is Europe's tallest measuring mast for wind energy. Conventional masts are only about 100 meters in height. The rotor blade of a modern turbine, however, easily reaches double that height. As astonishing as it may sound: Scientists know little about the dynamics of wind conditions up there. "Indeed, there are theories about how wind speed increases with height, yet these no longer apply at such great heights. Hence, actual measurement values are needed to further develop the models," explains Klaas.

For instance, trees decelerate ground-level winds and create turbulence, and it was previously not possible to draw readily available conclusions about the conditions at the upper regions based on these data. Thanks to the Fraunhofer researchers' measuring mast, this can now be done. Using ultrasound anemometers (special wind gauges), it records, in spatial terms, how fast and in which direction the wind is blowing, thereby rendering a precise depiction of the turbulence. Conventional vane anemometers moreover establish wind speed and direction at various heights. They additionally measure other meteorological factors, like air pressure, humidity and temperature. The figures on precipitation amounts and the duration of sunshine complete the data set. "We have achieved a unique sensory device that allows us to determine the impact of these parameters on wind conditions," says Klaas.

The detailed measurements not only help in the optimal alignment of wind turbines, but also in determining the appropriate dimensions. This is the precondition for ensuring, for example, that the turbines are built at the correct height and designed with no greater mass than necessary, which saves on expenses.

With the aid of the wind measuring mast, it should additionally be possible to develop standards for LIDAR (light detection and ranging), the new ground-based remote measurement process. The laser-optical measurement process is considered the key to wind profile measurements up to heights of several hundred meters. Due to the lack of standards, LIDAR remains unapproved as the sole measurement process for expert reports on wind, which are the basis for yield calculations. If successfully granted one day, thanks to the Fraunhofer measuring mast, then such approval would make expert reports on wind superfluous, because LIDAR would render measuring masts obsolete.



Specialists install the 200-meter high measuring mast.
(© Fraunhofer IWES/Klaus Otto) | Picture in color and printing quality: www.fraunhofer.de/press

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Wireless window sentinel

A bad weather front is fast approaching and a cloudburst is imminent. If you happen to be away from home, but have left a window open, either deliberately or because you forgot to check one room, you may be in for a wet surprise when you come home. However, it does not have to be like that: Thanks to a new sensor system, such situations can now be avoided. A sensor embedded in the window frame detects if a window is closed, cracked open or wide open and sends this information to a base station at the main door. When leaving the house, a resident can tell at a glance which windows are open and which closed. Since the system enables remote queries, users can even monitor windows via a smartphone. Researchers at the Fraunhofer Institute for Integrated Circuits IIS, based in Erlangen and Nuremberg, have developed the product in close collaboration with Seuffer, a Calw-based company which has been an IIS industry partner for over a decade.

The intelligent window monitor is based on the IIS-developed HallinOne® sensor – a 3-D magnetic field sensor that is already being used in mass-produced washing machines, where it determines the exact position of the drum. "We've adapted our technology for the window application. A fingernail-sized sensor embedded in the inner frame detects sash and handle positions by measuring any changes in the angle and position of a magnet that's embedded in the bottom of the sash. When you lock the window, for example, the magnet moves to the right," explains IIS engineer Klaus-Dieter Taschka. "The sensor even detects if a casement window appears to be properly latched, but has actually just been pulled shut. No other system can do this." In addition, the system is tamper-proof and so can help protect against break-ins. The magnet cannot be removed without the sensor detecting its removal.

Wireless communication

Also embedded in the frame is an RF node. Comprising a radio unit and a microcontroller, it uses the s-net® technology developed by IIS for extremely energy-efficient wireless data transmission to a base station. This can take the form of a PC, cell phone or tablet, even a room controller. "The s-net® wireless sensor network is a multi-hop network where sensor nodes exchange data both with each other and with master nodes," says Taschka. Nodes have a communication range of 20 to 30 meters, which defines the maximum distance between one window and the next. Multi-hop capability means the system can cover vast areas, making it suitable for use in businesses. Installed in an office building, it could provide front-desk security staff with window status information and so do away with the need for walk-through checks. Another feature of the window sentinel is that it requires no cables or batteries. The sensor draws all the power it needs from its surroundings. The underlying technology, known among experts as "energy harvesting", enables power to be derived from ubiquitous sources such as air currents, vibrations or in this case sunlight and ambient heat.

Thermoelectric generators embedded in the window frame transform heat into power. Solar cells attached to the outer window frame also help power the 3-D sensor. "Our tests showed that this works even in north-facing windows," says Andreas Buchholz, Head of Research and Development at Seuffer.

Obviously, the system is suitable for everyday use only if all sensors function reliably. To ensure that this is the case, each chip is equipped with a coil that creates a magnetic field as soon as power is applied. If a signal is emitted, then the sensor is intact. "The window monitor is the result of a vigorous exchange of ideas we've maintained over the years with Fraunhofer researchers," says Buchholz.

The window, which includes the sensor, magnet, RF node and solar cell, is currently available as a prototype. By the end of the year it is expected to be ready for mass production. Manufacturing will be done by Seuffer, which also developed the electronics and produced the housing.

The sensor nodes embedded in the window frame transmit the data via the s-net wireless sensor. The prototype of the RF node (left) pictured here will be installed in the sensor housing (right) of the finished system. (© Fraunhofer IIS) | Picture in color and printing quality: www.fraunhofer.de/press

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Turning ideas into products faster

Only around 0.3 percent of the world's water supply can be used directly as drinking water. At the same time, the world population is growing steadily, thus increasing the need for clean water constantly. Water treatment technologies such as reverse osmosis will be instrumental in ensuring that we have enough to drink in the future: A membrane filtration system removes substances such as salts, pesticides, viruses and bacteria from water. In early 2010, the specialty chemicals company LANXESS decided to enter a new field of business, water treatment. It planned to have a high-tech production facility built by the fall of 2011in Bitterfeld, the location of IAB Ionenaustauscher GmbH, a LANXESS subsidiary. This ambitious plan meant that both the product and the manufacturing technology had to be designed and ready for manufacturing in very short time. LANXESS intended to bring outside expertise on-board to engineer the automation and hit upon the Fraunhofer Institute for Factory Operation and Automation IFF right in the area.

The researchers had little time for preparation. "Research and development had to proceed in parallel, which is why we relied on virtual engineering from the outset," says Prof. Ulrich Schmucker, Manager of the Virtual Engineering Business Unit at the Fraunhofer IFF. "It enabled us to start on work very early, which would not get done in a conventional approach until the final stage of development."

Simulating filter elements on the computer

Since the membrane filter elements, which were to be manufactured at the production facility, did not exist yet, a team of experts der IAB GmbH and the Fraunhofer IFF first analyzed the product features on the computer with the aid of various simulations. This was necessary in order to determine important manufacturing parameters, such as speed, which also played a role later when the system was designed. Researchers subsequently used the virtual models of the semi-automatic system to run through and optimize the individual steps of the process. They were also able to estimate the manpower it would require.

Thus, the design engineers already had very clear specifications for the ensuing CAD. That was not all, though. The researchers from Magdeburg have developed a special method that makes it possible to start programming a control system already based on the relatively rough CAD model. Programming is usually not done until the end when the equipment has been built and hooked up. However, it is virtually impossible to modify the equipment any longer at that time. "We, on the other hand, connect the real control system to the virtual model. Then, we watch the movements of all of the parts relative to one another on the monitor. This enables the programmer to check the correctness of sequences, eliminate errors and exceptions or even perform collision

analyses," explains Prof. Schmucker. When necessary, the design engineer makes changes before the equipment has even been built.

Not least, consulting with a client becomes significantly easier. "Ideas about a user interface's appearance often tend to be very abstract at the beginning," explains Prof. Schmucker. "When the client has a clear mental picture, however, it is much easier to plan and identify the required control elements expediently." The decision to enter a new realm of development with VR models proved its worth for LANXESS, too. Jean-Marc Vesselle, Head of the Ion Exchange Resins Business Unit, is convinced that, "virtual engineering is certainly going to take on greater importance for us in the future."

Membrane elements have been being manufactured in Bitterfeld since the fall of last year. The experts from the Fraunhofer IFF have already started working on the follow-up technology: A fully automatic system will commence operation in September. Around 30 million euros are being invested in the new factory in Bitterfeld. Some 200 new jobs will be created there over time. Production facilities, laboratories, logistics areas and offices are going up on an area of 4000 square meters.

The membrane elements for water treatment are manufactured in the semi-automatic system in Bitterfeld. A single membrane element consists of a bundle of over 20 layers. It is aligned with a winding module and secured. The LANXESS employee (left) is holding such a module. (© LANXESS AG) | Picture in color and printing quality: www.fraunhofer.de/press

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Manufacturing crack-resistant lightweight components

Cars, roof structures and bridges should become increasingly lighter, with the same stability, and thus save energy and materials. New high-strength steel is superbly suited for the needed lightweight design, because it can also withstand extremely heavy stresses. Yet these materials also betray a disadvantage: with increasing strength their susceptibility to cold cracking rises when welded. These miniscule fractures might form as the welded joints cool off – typically at temperatures below 200°C. In a worst case scenario, the welding seams would crack. For this reason, many industrial sectors are reluctant to employ these promising high-strength steel.

Scientists at the Fraunhofer Institute for Mechanics of Materials IWM in Freiburg, in conjunction with the Chair of Joining and Welding Technology LFT at Brandenburg University of Technology Cottbus (BTU) developed a new process for making cold cracking more predictable. "We are able to compute the probability of cold cracking as early as the design stage of a component, and immediately run through corrective measures as well," explains Frank Schweizer of the IWM. Because whether such cold cracking occurs, and how quickly, depends on how high the concentration of hydrogen in the steel is, how the residual stress turns out, and how its microstructure is configured. Predicting the probability of cracking has been difficult until now. Manufacturers used to conduct expensive testing, for example by applying an increasingly higher tensile stress to a sample component, and then analyse what stress level would cause cracking. Not only are these tests time-consuming and cost-intensive, the findings cannot be applied to subsequent components on a one-to-one basis – because the geometry of the component has a decisive influence on crack formation. Even currently available computer simulations failed to deliver the desired predictive accuracy for real components.

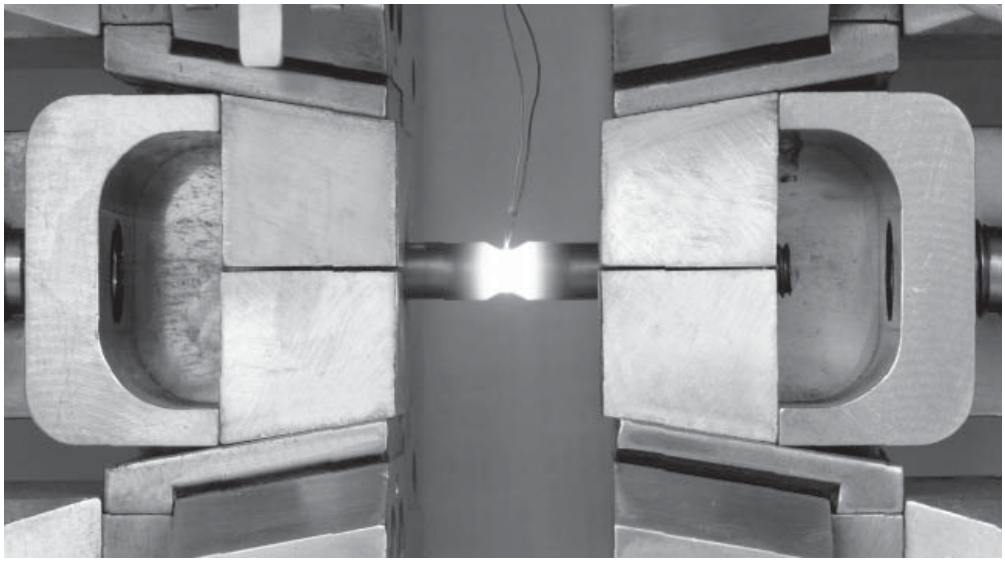
Lowering production costs, shortening development phases

The new approach could markedly reduce such costly methods in the future – and thus lower production costs while shortening development phases. The experts at LFT set up a special test, in order to precisely determine the cracking criterion on samples of high-strength steel. Beside typical influencing factors like hydrogen content, residual stresses and material structures that can be adjusted in at the same time, they also take into account the temperature gradients that emerge in the welding process.

The experts at IWM feed a computer simulation with this criterion in order to analyze the threat of cold cracking in random components and geometries. "This way, we can locate the areas on a welding seam at risk of cold cracking, for each point and at any time in the simulated welding process," explains Frank Schweizer. The researchers can also get a preliminary look at the effects of any countermeasures, and make the ne-

cessary adjustments. To do so, they transfert the results back into the simulation, in order to fine-tune them there.

In the future, with the aid of this process, manufacturers of vehicles and machines could be able to define non-critical welding parameters and limiting conditions for their materials in advance – and thus establish a substantially more efficient and safer production process. This is especially relevant to materials that are difficult to weld, with very narrow processing windows regarding welding parameters or the pre- and post-heating temperatures. Fraunhofer IWM and LFT, in cooperation with Robert Bosch GmbH and ThyssenKrupp Steel Europe AG, are currently testing their new process on laser beam-welded demonstration models made of high-strength steels.



In this test, the material sample is heated to welding temperature to determine its critical conditions for the formation of cold cracking. (© Chair of Joining and Welding Technology at the Brandenburg University of Technology) | Picture in color and printing quality: www.fraunhofer.de/press

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Measuring glucose without needle pricks

Sticking yourself in the finger day after day: For many diabetics, this means of checking blood glucose is an everyday part of life. Especially for patients with Type-1 diabetes, who always have to keep a close eye on their levels, since their bodies are incapable of producing the insulin to break down the glucose in the blood. Several times a day, they have to place a tiny drop of blood on a test strip. It is the only way they can ascertain the blood glucose value, so they can inject the correct amount of insulin needed. And this pricking is not only a burdensome: it may also cause inflammation or cornification of the skin. And for pain-sensitive patients, the procedure is agony.

The daily sticking of the finger may soon become a thing of the past, thanks to a diagnostic system with Fraunhofer technology built-in. The underlying concept is a biosensor that is located on the patient's body. It is also able to measure glucose levels continuously using tissue fluids other than blood, such as in sweat or tears. The patient could dispense with the constant needle pricks. In the past, such bioelectric sensors were too big, too imprecise and consumed too much power. Researchers at the Fraunhofer Institute for Microelectronic Circuits and Systems IMS in Duisburg have recently achieved a major breakthrough: They have developed a biosensor in nano-form that circumvents these hurdles.

Diagnostic system in miniature

The principle of measurement involves an electrochemical reaction that is activated with the aid of an enzyme. Glucose oxidase converts glucose into hydrogen peroxide (H_2O_2) and other chemicals whose concentration can be measured with a potentiostat. This measurement is used for calculating the glucose level. The special feature of this biosensor: the chip, measuring just 0.5 x 2.0 millimeters, can fit more than just the nanopotentiostat itself. Indeed, Fraunhofer researchers have attached the entire diagnostic system to it. "It even has an integrated analog digital converter that converts the electrochemical signals into digital data," explains Tom Zimmermann, business unit manager at IMS. The biosensor transmits the data via a wireless interface, for example to a mobile receiver. Thus, the patient can keep a steady eye on his or her glucose level. "In the past, you used to need a circuit board the size of a half-sheet of paper," says Zimmermann. "And you also had to have a driver. But even these things are no longer necessary with our new sensor."

Durable biosensor

The minimal size is not the only thing that provides a substantial advantage over previous biosensors of this type. In addition, the sensor consumes substantially less power. Earlier systems required about 500 microamperes at five volts; now, it is less than 100 microamperes. That increases the durability of the system – allowing the patient to

wear the sensor for weeks, or even months. The use of a passive system makes this durability possible. The sensor is able to send and receive data packages, but it can also be supplied with power through radio frequency.

The glucose sensor was engineered by the researchers at Noviosens, a Dutch medical technology firm. Since it can be manufactured so cost-effectively, it is best suited for mass production. These non-invasive measuring devices for monitoring blood glucose levels may become the basis for a particularly useful further development in the future: The biochip could control an implanted miniature pump that, based on the glucose value measured, indicates the precise amount of insulin to administer. That way, diabetes patients could say goodbye to incessant needle-pricks forever.

With this nano-sized biosensor, diabetes patients can measure their glucose levels with the fluid from the tears of their eyes. (© Fraunhofer IMS) | Picture in color and printing quality: www.fraunhofer.de/press

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