RESEARCH NEWS

04 | 2015 ||

1 Novel tissue substitute made of high-tech fibers

Regenerative medicine uses cells harvested from the patient's own body to heal damaged tissue. Fraunhofer researchers have developed a cell-free substrate containing proteins to which autologous cells bind and grow only after implantation. Samples of the new implants will be on show at the Medtec expo.

2 Saving energy with smart façades

Glass-fronted office buildings are some of the biggest energy consumers, and regulating their temperature is a big job. Now a façade element developed by Fraunhofer researchers and designers for glass fronts is to reduce energy consumption by harnessing solar thermal energy. A demonstrator version will be on display at Hannover Messe.

3 Reliable systems for recharging electric vehicles

The success of electric vehicle networks depends on economical vehicles – and efficient power grids. Existing power lines were not designed for the loads generated by electric vehicles. Fraunhofer researchers have developed prototype software to show grid operators how many electric vehicles can be connected to their local grid.

4 Plastic parts for internal combustion engines

Efforts to produce lighter vehicles necessarily include engine parts, such as the cylinder casing, which could shed up to 20 percent of its weight if it were made of fiber-reinforced plastic rather than aluminum – without added costs. Such injection-molded parts are even suitable for mass production.

5 Cost-effective production of magnetic sensors

They are found wherever other measurement methods fail: magnetic sensors. They defy harsh environmental conditions and also function in fluids. A new procedure is now revolutionizing the production of two-dimensional magnetic sensors: They now only cost half, and production time is reduced by 50 percent.

6 Measurement of components in 3D under water

Conveying systems for oil and gas, operated in the sea have many important underwater components. The maintenance of such components is elaborate and expensive, as measuring them is complicated. Fraunhofer researchers are presenting a compact 3D measurement system at the trade fair in Hannover.

The Fraunhofer-Gesellschaft is the leading organization for applied research in Europe. Its research activities are conducted by 66 Fraunhofer Institutes and research units at over 40 different locations throughout Germany. The Fraunhofer-Gesellschaft employs a staff of around 24,000, who work with an annual research budget totaling 2 billion euros. About 70 percent of this sum is generated through contract research on behalf of industry and publicly funded research projects. Branches in the Americas and Asia serve to promote international cooperation.

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Novel tissue substitute made of high-tech fibers

RESEARCH NEWS
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Donor organs or synthetic implants are usually the only treatment option for patients who have suffered irreparable damage to internal organs or body tissue. But such transplants are often rejected. Implants based on autologous cells are more likely to be accepted by the human organism. But in order to grow, these cells require a compatible structural framework. Researchers at the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB in Stuttgart are working on a project to develop suitable substrates – known as scaffolds – in collaboration with the university hospital in Tübingen and the University of California, Los Angeles (UCLA). Their solution is based on electrospinning, a process in which synthetic and biodegradable polymers such as polylactides are spun into fibers using an electrical charge. These fibers are then used to create a three-dimensional non-woven fabric.

Growing cells inside the patient's body

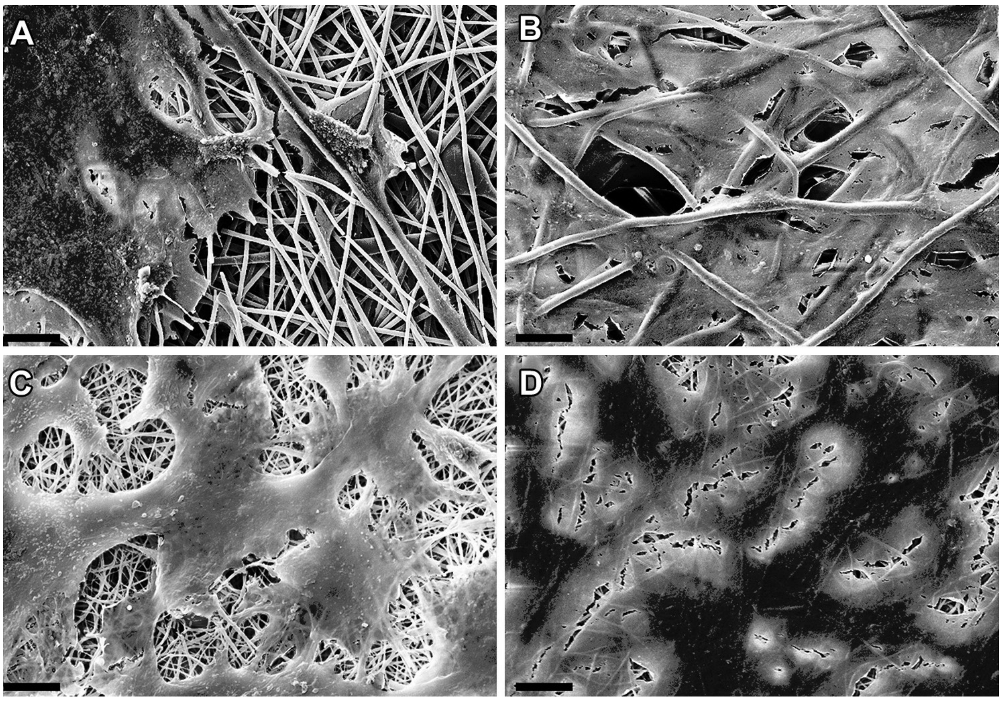
The scientists have chosen a novel approach in which proteins are added to the polymeric material during the electrospinning process, and become incorporated in the resulting hair-thin fibers. In this way, the material serves as a substrate to which the patient's own cells will bind after it has been implanted. "Electrospinning enables us to create a cell-free substrate on which cells can grow after it has been implanted in the patient's body. Each type of protein attracts specific cells, which adhere to the scaffold and grow there. By selecting the appropriate protein, we can build up heart tissue or regenerate other damaged organs," explains Dr. Svenja Hinderer, one of the research scientists working on this project at Fraunhofer IGB in Stuttgart.

The substrate is spun into a fine sheet and cut to the required size. To repair damage to the heart muscle, for instance, a scaffold corresponding to the extent of the damaged area is placed like a blanket over the muscular tissue. The polymeric fibers gradually degrade in the human organism over a period of approximately 48 months. During this time, the cells that bind to the proteins find an environment that is conducive to their growth. They construct their own matrix and restore the functions of the original tissue.

Successful bioreactor test results

The results of initial laboratory experiments and bioreactor tests have been very successful so far. The researchers have been able to demonstrate that esophageal/tracheal cells, which are difficult to culture in-vitro, are capable of binding to decorin protein fibers in the substrate and growing there. Another protein – the stromal-cell derived growth factor SDF-1 – binds with progenitor cells, a special type of stem cell necessary for constructing heart valves and for regenerating heart muscle cells after an infarction. "The implants we have fabricated using electrospinning demonstrate the same mechanical and structural properties as a normal heart valve. Like the original version, they close and open at a blood pressure of 120 to 80 mmHg during tests in a bioreactor," says Hinderer. The next step for the researcher and her colleagues is to test the protein-coated scaffolds in animal models.

The hybrid materials composed of polymeric and protein fibers can be produced and stored in large quantities. The IGB team is working to bring the novel substrate to market as a rapidly implementable alternative to conventional heart valve replacements. "We can't yet say how long this will take, though," comments the researcher. One of the advantages of cell-free implants is that they are classified as medical devices and not as novel therapeutic drugs, which means less time waiting for approval. "Even so, the process of obtaining approval for medical devices that are populated with human cells prior to implantation is very long and expensive," explains Hinderer. The researchers will be presenting samples of the polymeric scaffolds at the Medtec expo in Stuttgart from April 21 to 23, in the joint Fraunhofer booth (Hall 7, Booths 7B04/7B10). Exhibits also include a bioreactor for cell culture on these substrates.



The high-tech fibrous material can be used to replace human tissue. These images taken with a scanning electron microscope show cells adhering to the electrospun substrate.
(© Fraunhofer IGB) | Picture in color and printing quality: www.fraunhofer.de/press

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Saving energy with smart façades

RESEARCH NEWS
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In Germany, buildings account for almost 40 percent of all energy usage. Heating, cooling and ventilating homes, offices and public spaces is expensive – and offices with huge glass façades are one of the worst offenders in terms of energy wastage. In the summer, these buildings begin to resemble giant greenhouses that take an enormous amount of effort to cool, while in winter heating requirements shoot up because of insufficient heat insulation for the glass surfaces. In a bid to cut energy consumption, researchers from the Fraunhofer Institute for Machine Tools and Forming Technology IWU in Dresden have teamed up with the Department of Textile and Surface Design at Weissensee School of Art in Berlin to develop façade components that respond autonomously to sunlight and its thermal energy.

A thermally reactive fabric blind for glass façades

"We don't need any power since we can rely solely on thermal energy to control the façade element," says André Bucht, researcher and department head at Fraunhofer IWU. "The challenge in this project was how to bring together innovative technology and design," adds Prof. Christiane Sauer from the Weissensee School of Art. "Having designers and scientists work together is the key to pioneering concepts for smart building envelopes." The demonstrator is based on a concept by design student Bára Finnsdottir, and consists of a matrix of 72 individual fabric components shaped like flowers. Each textile module has shape-memory actuators integrated into it; thin 80-millimeter-long wires of nickel-titanium alloy that remember their original shape when exposed to heat. Should the façade heat up due to the sunlight falling upon it, the wires are activated and noiselessly contract to open the textile components. The exposed surface of the façade is covered and sunlight can no longer penetrate into the room. As soon as the sun disappears behind a cloud, the components close again so that the façade is transparent once more. The effect is thanks to a special lattice arrangement in the material. "When you bend the wire, it keeps that shape. Then when you expose it to heat, it remembers the shape it had originally and returns to that position. Picture the façade element as a sort of membrane that adapts to weather conditions throughout each day and during the various seasons of the year, providing the ideal amount of shade however strong the sun," says Bucht.

Designed for large expanses of glass, the sun shield can be attached either on the outer layer of glass or in the space inbetween in the case of multi-layer façades. The innovative structure is easy to retrofit and comes with a range of design options, allowing you to choose the pattern, shape and color of the individual components. "For instance, you might want to replace the circular design with triangles or a honeycomb arrangement. You can also control the level of sun exposure for individual sections of the façade – just the top left area, for instance. What's more, the membrane even fits on curved areas of glass. We've reached the point where the design has become independent of the shape of the building," says the researcher. Bucht and his team will be presenting the wealth of design options at Hannover Messe. Visit them in Hall 2, Booth C22 from April 13-17 to see the demonstrator in action. Visitors will be able to actively control the façade using a tablet app specially designed for the purpose.

In the next phase of the project, the researchers want to collaborate with industry partners to develop a range of prototypes for private and office buildings, with the intention of testing them long-term on a detached house and on buildings at the institute. "One priority will be to design fabric elements that are stable enough to withstand any weather," says Bucht of the work ahead. The plan is to have versions for new builds as well as variants suitable for retrofitting onto existing buildings. The goal is for the systems to be ready for market launch by mid-2017.

But the researchers' ideas for the façade of the future don't end there: future plans include climate functions for the façade element, for instance variable heat insulation. "It might be possible to store solar thermal energy and then release it when needed to heat the interior, for instance at night. Another idea is to coat the flower fabric components with malleable, organic solar cells in order to generate electricity that can be used within the building."

The façade element operates using integrated shape-memory alloys and so doesn't require an external power source. (© Wilm Ihlenfeld/Fotolia, Fraunhofer IWU) | Picture in color and printing quality: www.fraunhofer.de/press

Reliable systems for recharging electric vehicles

RESEARCH NEWS
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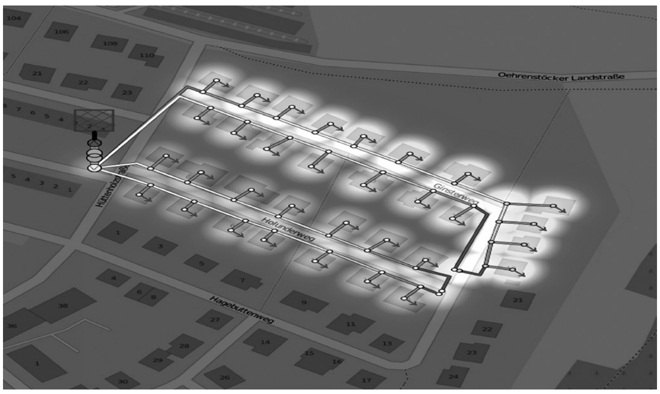
The rising number of electric vehicles on the road is putting grid operators under pressure. Low voltage networks for domestic consumers are not designed for the kind of loads that are generated by recharging electric vehicles at home. “A vehicle draws up to 22 kilowatts (KW) of power. So if you have multiple vehicles plugged in at the same time, then current grids quickly reach their limits,” says Dr. Michael Agsten from the Advanced System Technology (AST) department at the Ilmenau site of the Fraunhofer Institute of Optronics, System Technologies and Image Exploitation IOSB. Together with his team of researchers, Agsten has developed a software program that shows grid operators how much load their low voltage network can handle. This enables them to draw conclusions on how many electric vehicles can be connected to the grid without pushing it to its limits. Grid operators can then plan in advance and find answers to key questions. For example: how will connecting one more vehicle affect the load distribution? At what point should we invest in our networks to ensure we maintain enough capacity? Is it better to spend money on new copper cables or invest in smart charge spots? A prototype of the software program has already been created as part of the “Managed Charging 3.0” project sponsored by the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB). “The IT platform is already running very smoothly in the laboratory with test data. In the next stage we’re hoping to analyze real distribution grids,” says Agsten.

Fast random sampling

The software shows how many charging processes can run simultaneously without hitting the limits set by statutory requirements or by the grid operator. Each electricity substation typically supplies power to 150 or more households. If you assume that a certain proportion of households will own an electric vehicle in the future and plug the vehicle in at some point in time, then you are left with an inconceivably high number of charging scenarios. That’s because it’s impossible to predict which households will charge their electric vehicles at any one point in time. “It’s impossible to calculate that in the time available,” Agsten explains. The researchers therefore decided to simulate their model using the Monte Carlo method, a form of stochastic modeling. The aim is to produce a group of combinations that is as heterogeneous as possible. The number of these combinations is significantly smaller than the total number of all possible combinations. “It’s far quicker to analyze somewhere between 1,000 and 10,000 cases, and that still gives you a very good approximate value,” says Agsten. In a matter of seconds the software program shows the degree of overload risk and how many electric vehicles can be charged simultaneously in a local grid.

Distribution grid operators can use these figures to protect their power grids from long-term damage and sudden outages. In Germany there are around 560,000 local grids which are divided among approximately 800 grid operators. Each operator is responsible for the reliable and stable operation of their distribution networks and local grids and is required to meet demand by carrying out measures such as smart management and grid expansion where necessary. These companies do not have enough personnel to manually calculate how many electric vehicles can safely be connected to each individual distribution network. Even if they did, the cost would be prohibitive. It took relatively little time to calculate how many household appliances such as washing machines, ovens, televisions and computers could be connected simultaneously before limits were reached. And in fact the standard upper limit of up to 44 KW/63A per household has only been tested in exceptional cases. But nobody figured in the power required to charge electric vehicles. “Charging electric vehicles leads to a significantly higher household power draw – and the problem is exacerbated if people charge multiple vehicles at home at different times of the day,” says Agsten. Key parameters such as voltage stability, component thermal load and voltage imbalance fluctuate constantly based on the changing volatile load of electric vehicles according to time and place. Each time another electric vehicle is plugged in, this increases the number of possible combinations of simultaneous charging situations distributed geographically and over time. The current processes used for testing and installation are unable to take all the local boundary conditions into account. “As the power draw continues to steadily increase, network operators will need to know as early as possible how much room they still have for maneuver. Otherwise they won’t know that the limits have been reached until their customers actually start reporting problems,” says Agsten.

The platform developed by Fraunhofer IOSB is designed to tackle the low voltage network, which is the lowest level of the electrical transmission and distribution grid. It uses a series of stages in the grid to connect the plug sockets in people’s houses with the high and extra high voltage networks. These higher levels of the grid will be drawing on an increasing proportion of fluctuating renewable energy sources in the future. Electric vehicles could help balance out these fluctuations because they can also be used to store energy. “But that will work only if the power grid lets them connect in the first place!” Agsten notes.



When multiple electric vehicles plug in at the same time, existing power grids quickly reach the limit of their capacity. Fraunhofer has developed a software program that shows grid operators how much load their low voltage network can handle. (© OpenStreetMap/ Fraunhofer IOSB-AST) | Picture in color and printing quality: www.fraunhofer.de/press

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Plastic parts for internal combustion engines

RESEARCH NEWS
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It's self-evident that cars must become lighter in order to reduce fuel consumption. For most car designers this principally means body parts, but the powertrain system, which includes the engine, also accounts for a large proportion of the vehicle's weight. Until now, carmakers have relied on aluminum to reduce the weight of engine components such as the cylinder block. In the future, car manufacturers will be able to achieve further weight savings by designing cylinder blocks in which certain parts are made of fiber-reinforced plastics. An experimental engine developed by the Fraunhofer project group for new drive systems (NAS), which forms part of the Fraunhofer Institute for Chemical Technology ICT, in collaboration with SBHPP, the high-performance plastics business unit of Sumitomo Bakelite Co. Ltd., Japan, demonstrates this principle. "We used a fiber-reinforced composite material to build a cylinder casing for a one-cylinder research engine," reports Dr. Lars-Fredrik Berg, who is the project leader and manager of the research area Lightweight Powertrain Design at the Fraunhofer Project Group for new drive systems. "The cylinder casing weighs around 20 percent less than the equivalent aluminum component, and costs the same." It seems an obvious solution, but getting there involved numerous technical challenges, because the materials used have to be able to withstand extreme temperatures, high pressure and vibrations without suffering damage. That plastics possessed these qualities was recognized back in the 1980s, but at that time it was only possible to produce this types of parts in a small volume and by investing a lot of effort in the form of manual labour – a no-go for the automotive industry, in which cylinder blocks are mass-produced in millions of units.

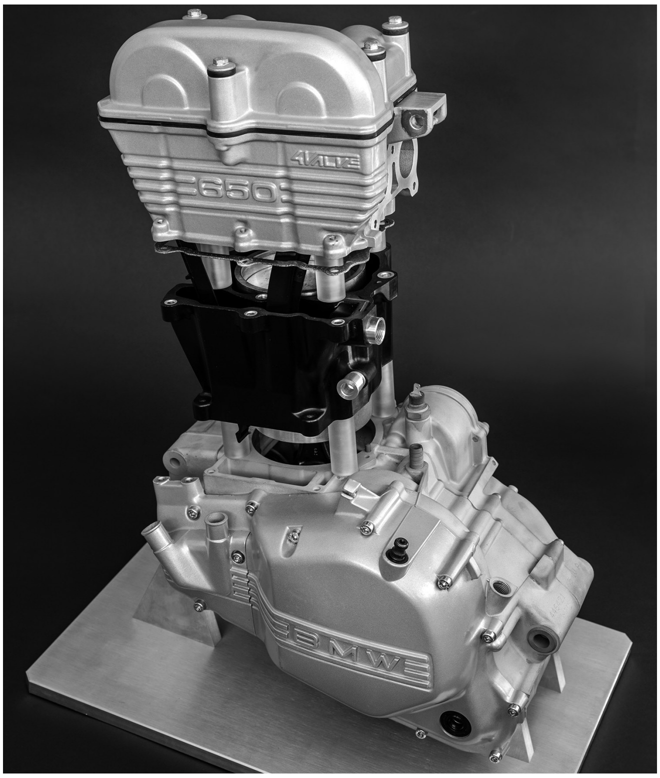
So what did the researchers do to ensure that their engine would be sufficiently robust? "First we looked at the engine design and identified the areas subject to high thermal and mechanical loads. Here we use metal inserts to strengthen their wear resistance," explains Berg. One example is the cylinder liner, inside which the piston moves up and down millions of times during the life of the vehicle. The researchers also modified the geometry of these parts to ensure that the plastic is exposed to as little heat as possible.

Glass-fiber-reinforced phenolic resin

The characteristics of the plastic material also play an important role. It needs to be sufficiently hard and rigid, and resistant to oil, gasoline and glycol in the cooling water. It must also demonstrate good adherence to the metal inserts and not have a higher thermal expansion coefficient than the metal – otherwise the inserts would separate from the substrate. Berg's team uses a glass-fiber-reinforced phenolic composite developed by SBHPP, which fulfills all of these requirements and comprises 55 percent fibers and 45 percent resin. A lighter-weight but more expensive alternative is to use a carbon-fiber-reinforced composite – the choice depends on whether the carmaker wishes to optimize the engine in terms of costs or in terms of weight.

The researchers produce these components from granulated thermoset plastics using an injection molding process. The melted composite material, in which the glass fibers are already mixed with the resin, hardens in the mold into which it was injected. The scientists analyzed the process using computer simulations to determine the best method of injecting the material in order to optimize the performance of the finished product. The process is compatible with mass production scenarios and the manufacturing costs are significantly lower than those for aluminum engine parts, not least because it eliminates numerous finishing operations.

A prototype of this engine will be presented at this year’s Hannover Messe, which takes place on April 13-17 (exhibit in Hall 2, Booth C16). Test runs of the new engine have been completed successfully. “We have proved that it is capable of the same performance as conventionally built engines,” says Berg. Moreover, it promises to offer further advantages such as lower running noise as against engines relying exclusively on metal parts. Initial data also indicates that the amount of heat radiated to the environment is lower than that generated by aluminum-based engines. The scientists intend to take their research further by developing a multi-cylinder plastics-based engine, including the crankshaft bearings.



Demonstration model of the experimental engine with lightweight cylinder casing to be presented at the Hannover Messe. (© Fraunhofer ICT) | Picture in color and printing quality: www.fraunhofer.de/press

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Cost-effective production of magnetic sensors

RESEARCH NEWS
04 | 2015 || Topic 5

Where did you have to go? Turn right here – or was it the next turn? A glance at the smart-phone helps: Various apps provide maps and turn them in the right direction, adjusting them to north. Navigation devices are equally »clever«: They too show the right direction even before the car sets off. This is made possible by a magnetic sensor. It establishes how the device is being held in relation to the earth's magnetic field. The market is highly competitive: Every cent counts in the price of the sensors. Until now, manufacturers have relied on several cheap one-dimensional sensors. The disadvantage: They are less sensitive and do not work as accurately as two-dimensional models.

In future however, compact two-dimensional sensors could find their way into smartphones. Researchers from the Fraunhofer Institute for Electronic Nano Systems ENAS, in Chemnitz have optimized the corresponding manufacturing process. »The costs and manufacturing time for two-dimensional magnetic field sensors drop by half«, says Dr. Olaf Ueberschär, group manager at the ENAS.

Sensors »from one piece«

The reason for this drop in costs lies in the method of production: The scientists produce the sensors from one piece of material – hence in a totally different way than ever before. Because even a one-dimensional sensor needs two microelectronic half-bridges, whose applied magnetic fields point in opposite directions. As the basic materials specify a magnetization direction, meaning that the magnetic field within them is already aligned, two different pieces of material used to have to be joined – an elaborate and also expensive procedure. Two half-bridge sensors or four pieces of material were required for two-dimensional sensors.

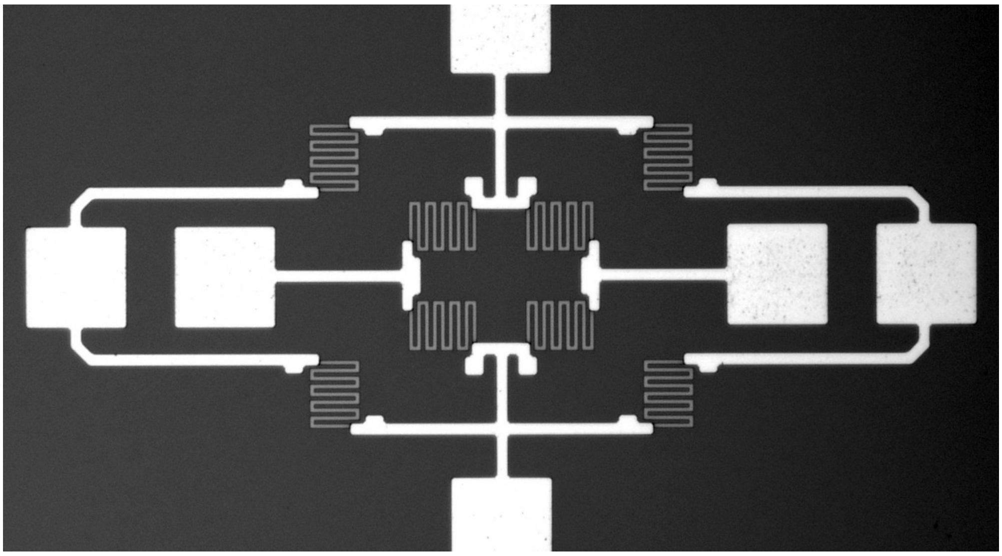
»For the first time we are able to produce not only the full bridges, but also the two-dimensional sensors monolithically – from one piece«, Ueberschär adds. For this purpose, the researchers separate a layer of material off a wafer and etch the desired structure out. The trick lies in the subsequent laser treatment: This enables the scientists to adjust the preferred magnetic directions at will.

As small as the dot on the "i"

Another advantage: The new sensor is not even quite a square millimeter in size, thus being only about half the size as former models. The smaller the mini-chips are, the more applications they are suitable for. For example for magnetic field cameras, containing numerous sensors in several lines and columns, recording magnetic data. If a high resolution is to be achieved, the sensors must be as small as possible – only then do they fit in close proximity to one another and do not mutually interfere.

Magnetic sensor technology is not restricted to smart-phones. It is used wherever adverse ambient conditions prevail and other measurement methods would fail – for instance in fluids or hot oil baths. They are also found in cars, for example in fully electronic gear levers such as are installed in newer vehicles in the center console or on the steering wheel. And in medical diagnostics they are used to trace tropical diseases and other viruses and bacteria.

Experts will present prototypes of the two-dimensional sensors at the Sensor + Test trade fair from May 19 to 21, 2015 in Nuremberg (Hall 12, Booth 12-531 / 12-537). It will however take about another year before the sensors can actually be used in products.



View from above of the prototype of a two-dimensional magnetic sensor. (© Fraunhofer ENAS) | Picture in color and printing quality: www.fraunhofer.de/press

Measurement of components in 3D under water

RESEARCH NEWS
04 | 2015 || Topic 6

The maintenance of underwater technical systems is elaborate and expensive. Pipes, flanges and connections of conveying systems for oil and gas at sea, for example, must first be measured for this purpose. The measurements serve to correctly assess the extent of damage – caused by corrosion, for instance, or by other defects – and to initiate suitable repair interventions. The Fraunhofer Institute for Applied Optics and Precision Engineering IOF in Jena is presenting a system at the Hannover trade fair from April 13 to 17 (Hall 13, Booth E26), which measures underwater components and provides this information as 3D data. The sensor and camera technology has approximately the size of a shoe box and can be held by a diver just like an underwater camera. It is currently designed for use at a water depth up to 40 meters. The prototype was created within an international research project together with the 4h JENA engineering GmbH and the Norwegian Research Institute Christian Michelsen Research (CMR). The Thuringia Landesentwicklungsgesellschaft (state development company) was the promoter. »In the next step we want to optimize the 3D measurement system for greater depths and broader underwater application fields«, says Dr. Peter Kühmstedt, scientist at the IOF.

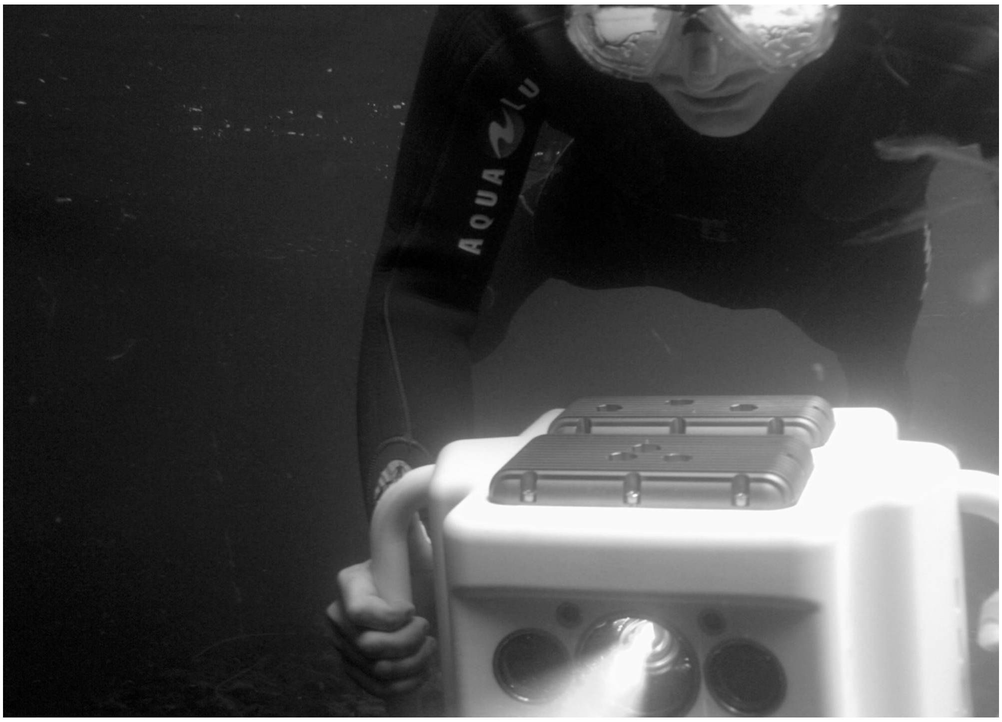
New 3D system: small, lightweight and extremely robust

During the project, the IOF was responsible for making 3D measurement technology suitable for underwater use. The highlight: The scientists managed to accommodate the entire control system and electronics as well as the computer and display technology in a very confined space: »The system is no larger than 20 cubic decimeters and weighs less than 11 kilograms«, says Kühmstedt. Despite its complex technology it must still be easy to operate, because divers are limited in their movements by the water and their equipment. The researchers have adapted the operating and representation software of the system to guarantee this: Only a few buttons go outwards. The temperature is constantly monitored to keep the device mechanically and thermally stable, because under water, temperatures may fluctuate immensely depending on depth and sea current. Light conditions also differ from those on land: There are optical refractions at the interface between the device and the water. A special calibration strategy for the measurements compensates for that. A further drawback: In the water, everything runs via wires and not via radio – therefore the scientists have to design the cables in a very compact manner.

»Under water, things are ten times more expensive. It is a large cost aspect for energy and raw material conveying companies to have their systems maintained at sea. The problem: The technologies currently available for the measurement of components are either too slow or too far away from the actual application. This is why we have developed this prototype together with the industry«, says Kühmstedt.

4h JENA engineering was responsible for the development of the housing and the system cladding, and CMR for the integration of additional sensors.

The 3D measurement system successively depicts several striped patterns onto the surface of the component to be examined by means of a projector, while at the same time taking pictures of the object are taken with two cameras. Based on the series of stereo photos taken and on the active pattern structure seen on the surface, the technology is able to exactly determine the shape of the object. The diver needs 0.2 seconds for each 3D scan and can check under water whether they are usable. Once back on land or on the ship, he can then load the data to a computer, which evaluates the information and makes suggestions for possible repair measures. »For example it can be decided whether the rust has corroded too deeply or if the defect in the pipe presents a problem or not«, says Kühmstedt.



The 3D measurement system co-developed by scientists from the Fraunhofer IOF, reminds us of an underwater camera. Divers can operate it by simply pressing a button to measure components. (© Fraunhofer IOF) | Picture in color and printing quality: www.fraunhofer.de/press

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