Fraunhofer

RESEARCH NEWS

11 | 2014 ||

1 Electric cars without drivers

E-Mobile will park independently in the future and will also be able to find the next charging station without a driver. Researchers are working on electric cars that can travel short distances autonomously. On the basis of cost-effective sensors, they are developing a dynamic model that perceives the environmental situation.

2 Detecting leaks in biogas plants by laser

Servicing biogas plants is challenging. Leaks from which methane escapes are particularly problematic – from a security, a technical, an economic as well as an environmentally friendly perspective. Researchers are working on a technique that helps to better detect leaks. In this process, a laser discovers the leaks from several meters away.

3 Fewer surgeries with degradable implants

Until now, in cases of bone fracture, doctors have used implants made of steel and titanium, which have to be removed after healing. To spare patients burdensome interventions, researchers are working on a bone substitute that completely degrades in the body. Towards this end, material combinations of metal and ceramic are being used.

4 Health screening for industrial machines

Germany's Industry 4.0 initiative aims to develop industrial machinery with built-in intelligence based on smart self-monitoring functions. Researchers have now come a step closer to the ideal of a self-maintaining machine. A technology developed as part of the iMAIN project provides real-time online monitoring of unprecedented quality.

5 Versatile bonding for lightweight components

New materials are making cars, planes and all sorts of other things lighter. The catch is that many of these materials can't be welded. Now there's an alternative joining method available – gradient adhesives provide an extremely good way of ensuring joined parts stay joined for their entire service life and hold up well in the event of a crash.

6 A coating that protects against heat and oxidation

Researchers have developed a coating technique that they plan to use to protect turbine engine and waste incinerator components against heat and oxidation. A topcoat from micro-scaled hollow aluminium oxide spheres provides heat insulation, in the lab, already proved more economical than conventional techniques.

The Fraunhofer-Gesellschaft is the leading organization for applied research in Europe. Its research activities are conducted by 67 Fraunhofer Institutes and research units at over 40 different locations throughout Germany. The Fraunhofer-Gesellschaft employs a staff of around 23,000, 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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Electric cars without drivers

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Whoever got his driver's license twenty years ago and is back in a car for the first time is going to be rubbing his eyes in amazement. Electronic helpers warn of a possible collision when parking and keep the necessary distance to the car ahead during traffic. There are lane departure, crosswind, blind spot and high beam assistants, not to mention the anti-lock system. The car is taking over step by step in the cockpit. Researchers at the Fraunhofer Institute for Manufacturing Engineering and Automation IPA are one step ahead: They are dedicated to automated driving and are working on the vehicles of tomorrow, which can drive through traffic without human assistance. In this process, the Stuttgart engineers are particularly keeping an eye on electric cars.

The specialty of the researchers at the IPA is the development of robots. In the institute building, there is a prototype that independently finds its way on its four wheels through unknown territory. The challenges that are to be mastered are similar to those for automated driving. Here, as well, sensors need to recognize the environment so that the vehicle can navigate around obstacles and find its goal. Why not take advantage of that experience and apply it to the car, say the engineers in Stuttgart. That is why, one and a half years ago, an interdisciplinary team of computer scientists, mathematicians, electrical engineers and mechatronics engineers launched the project Afkar (a German abbreviation for "autonomous driving and intelligent chassis concept for an all-electric vehicle").

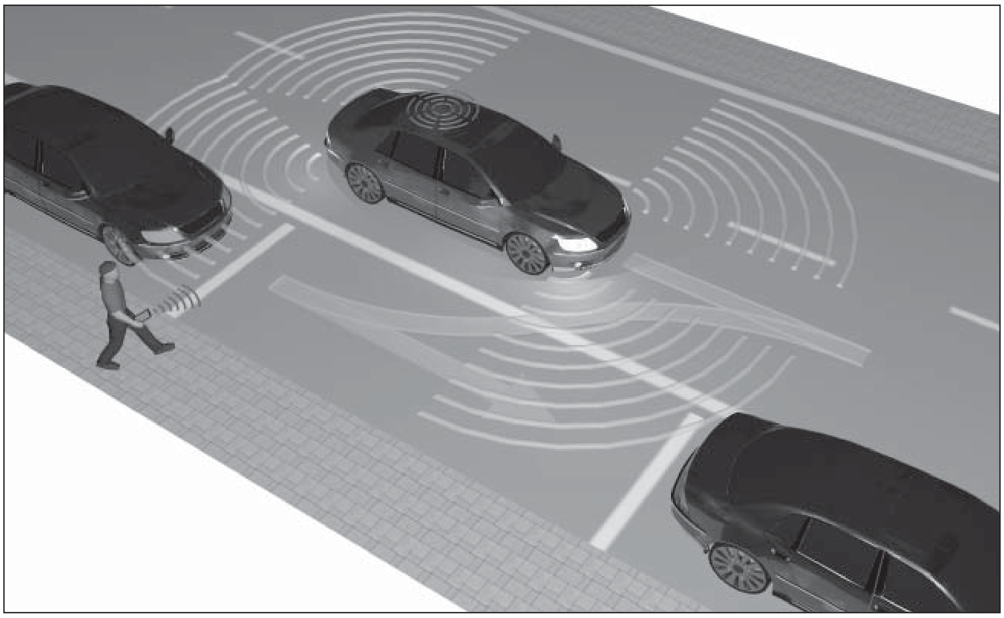
In a first step, the electric car is intended to learn to find a parking space and to park without a scratch. The idea behind this is that the car should be able to recharge itself with electricity without human help. This would be particularly important for car-sharing. Imagine the following scenario: The driver easily parks the car in a properly equipped parking garage on any randomly available parking space. The car takes care of everything else itself. It communicates via a wireless interface with the charging station and the parking garage management. In this process, it provides information about its charge level and its location. If the battery is empty and a charging station is free, it maneuvers in the corresponding parking bay and is charged inductively, without a cable. Then it makes room for the next electric car and rolls to a free parking space. In this way, the few existing charging stations can be used effectively.

Necessary technology is available

"The technology needed for this scenario is already available," says Afkar project manager Benjamin Maidel. He is referring to the robots of the institute that find their way easily in a known environment, such as a factory floor. Rebuilding a similar car does not take a lot of effort. Many modern cars already have most of the sensors that are required for this. The data that these devices collect just have to be combined and interpreted accordingly so that they provide a picture of the environment. The Fraunhofer experts are currently developing the necessary technology with the help of complex simulation programs. Soon, they want to test the results in practice on a demonstration vehicle.

It becomes more difficult when a car is intended to move autonomously in traffic. This requires sensors that can look hundreds of meters ahead as well as software that can react to any unforeseen events, whether that's a building site, a thunderstorm or snow. Maidel and his team are focusing on cameras, ultrasound, radar and laser scanners that perceive the surrounding area up to a distance of 200 to 300 meters.

The Afkar group will first go with their test car to a cordoned-off test area. For public roads, a special permit is required. "Whether autonomous driving makes a breakthrough will be decided, along with the right price, by customer acceptance and the legal framework. For example, the liability for accidents has to be re-regulated. The technology will probably conquer the market step by step", says Maidel. The advantages are obvious – particularly for car-sharing vehicles. Any customer could use his smart phone to call a car, which would then drive to the desired location. Car-sharing companies could utilize their fleets more fully than they do today.



Autonomous vehicle in the car-sharing operation: After the renter has called for the car, it navigates autonomously to the pick-up area. (© Fraunhofer IPA) | Picture in color and printing quality: www.fraunhofer.de/press

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Detecting leaks in biogas plants by laser

RESEARCH NEWS
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There are nearly 8,000 biogas plants today in Germany. They use biomass-derived gas to generate electricity and heat. In 2013, the operators produced a total of 26.42 terawatt hours (TWh) of electricity. This represents about 17 percent of the gross electricity generation from renewable energies. In Germany, 7.5 million households are now provided with electricity in this way. The requirements for the operation and maintenance of gas plants are high. Leakage is particularly problematic. Even small leaks from the joints of the gas lines or fermenters can have consequences: Escaping methane can result in fires, economic damage and a worsening of the carbon footprint of the generated electricity.

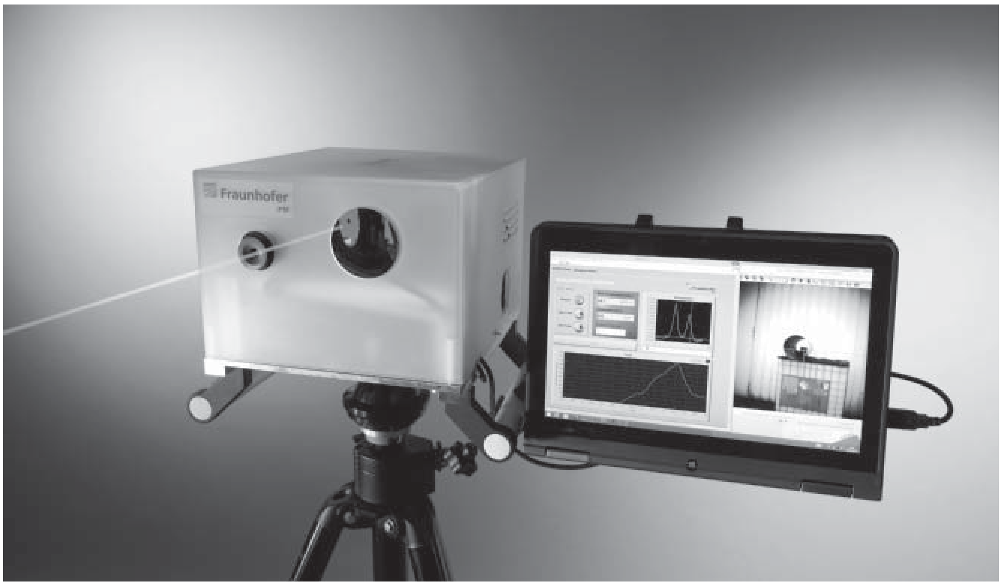
A technology is still lacking which allows operators to track down leaks in all system parts quickly, inexpensively and safely. In a project funded by the German Federal Ministry of Food and Agriculture (BMEL), researchers and a measuring equipment manufacturer are now addressing this issue. After one and a half years, the experts have developed a demonstrator that, without making contact, detects biogas or natural gas escaping from leaks through the use of a laser. Faster and more accurate than had previously been possible. The project involved the Fraunhofer Institute for Physical Measurement Techniques IPM in Freiburg, the Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT in Oberhausen and the measuring instrument manufacturer Schütz GmbH Messtechnik from Lahr.

Clearly identifying methane

The technology developed at the Fraunhofer IPM is based on optical emission and backscattering spectroscopy. In the process, the light of a strong laser beam detects escaping methane. Simultaneously, the gas irradiates part of the light back. The scientists analyze this proportion and determine the gas concentration from the absorption spectrum of the escaping substance. Since the gas spectrum is very precise, only methane is very selectively measured, and not any other gases. The technology is located in a box-shaped demonstrator. It stands on a three-legged tripod and is directed at the part of the equipment which is to be inspected. The optical portion of the measurement system comprises the laser, detector, camera and range finder. A connected tablet PC collects the data and evaluates it. The screen displays the graphically edited information concerning the escaping methane and the exact position of the leak. Measurements from up to 15 meters of distance are possible.

Researchers can measure very precisely with the system: They have adapted the wavelength of the laser optimally. A common flange size of joints of about 15 cm is measured with three to four measurement procedures. In addition, the technology detects excessive gas concentrations in rooms and determines when these are dangerous to humans. The researchers calculate the concentration using the data from the built-in range finder. The operator also knows how much gas has already escaped. This is another unique feature of the new system.

Dr. Johannes Herbst, measurement technology expert at the Fraunhofer IPM, expects the technology to be ready for the market in the next three to five years. In the laboratory, the researchers are currently honing in on other functions. They have succeeded, for example, in detecting methane without the backscattered light. For this purpose, the gas itself is illuminated by a strong laser. "In the future, the measurement team will be able to easily check the entire system from the ground. It used to be necessary to climb ladders and identify the leaks on the spot," said Herbst.



The laser-based system measures escaping biogas without contact – even from several meters away. (© Fraunhofer IPM) | Picture in color and printing quality: www.fraunhofer.de/press

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Fewer surgeries with degradable implants

RESEARCH NEWS
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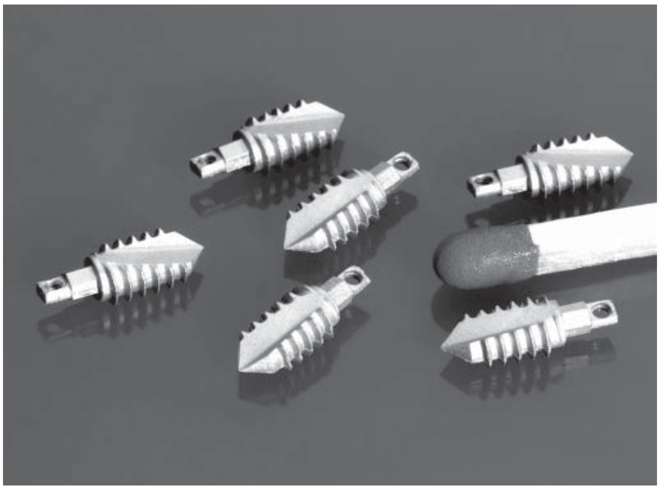
No other joint in the human body is as highly mobile as is the shoulder. However, it is also very sensitive and prone to injury, with athletes being particularly affected. The most common complaints include tendon rupture, which have to be treated surgically. The surgeon fastens the cracks using suture anchors. Such implants used to be made of titanium or non-degradable polymers – with the disadvantages that either they remain in the body even after healing has occurred or doctors have to remove them in a second procedure. To avoid this, researchers at the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM in Bremen have developed load bearing, biodegradable implants that are completely degraded in the body. In the first step, they have used powder injection molding to manufacture a suture anchor, which is available as a demonstrator. The researchers will present it from November 12th to 14th at the COMPAMED trade fair in Düsseldorf.

Calcium phosphate stimulates the healing process of the bone

"With the implant, severed tendons can be anchored to the bone until they have grown again. Since the function of the fixing element is satisfied after the healing process, it is no longer needed in the body. If implants or protheses that are as wear resistant as possible are required – such as in an artificial hip joint – metallic alloys such as titanium will certainly continue to be used. However, for plates, screws, pins and nails which should not remain in the body, there are other requirements," says Dr. Philipp Imgrund, manager of the Medical Technology and Life Sciences business field at IFAM. In the project "DegraLast", IFAM has worked jointly with the Fraunhofer Institutes for Laser Technology ILT, for Biomedical Engineering IBMT and for Interfacial Engineering and Biotechnology IGB in establishing a materials and technology platform to produce degradable bone implants for use in trauma surgery and orthopedics. These materials are to be gradually absorbed by the body while, at the same time, new bone tissue is formed. Ideally, the degree of degradation is adapted to the bone growth so that the degradation of the implant meshes with the bone formation. For this reason, the scientists are developing materials with specifically adjustable degradation. The challenge: The implants have to be mechanically stable enough during the entire healing process so that they are able to fix the bone in place. At the same time, they cannot have any allergenic effects or cause inflammation. The researchers at IFAM are relying on metal-ceramic composites. A metal component based on an iron alloy is being combined with beta-tricalcium phosphate (TCP) as the ceramic component. "Iron alloys corrode slowly and ensure high mechanical strength, while ceramic decomposes quickly, stimulates bone growth and aids the ingrowth of the implant", Imgrund says to explain the advantages of this material combination.

In order to be able to manufacture the material composite, the researchers have turned to the powder injection molding process. It offers the ability to produce complex structures cost-effectively and in large numbers. Properties such as density and porosity can be controlled selectively – an important factor, since high density and low porosity result in high mechanical strengths. Another advantage: The materials are available as powders and can be mixed in any proportion prior to processing. But what proportion is the right one? In laboratory experiments, the researchers have found the optimum composition of the materials for the suture anchor. The demonstrator consists of 60 percent iron and 40 percent ceramic. "It is important to determine the right amount of ceramics as a function of the powder amount. If the proportion is too high, the material will be brittle. On the other hand, the tricalcium phosphate accelerates the degradation of the implant," says Imgrund. The researchers have succeeded in doubling the degradation rate from 120 to 240 micrometers per year in the laboratory model. The shoulder anchor would be absorbed by the body within one to two years.

While shaping processes such as powder injection molding are especially suited in large quantities as fixation elements for standard implants, additive manufacturing methods are used to produce individual implants – such as for bone replacement in the skull area – or implants with defined pore structure. The researchers from ILT who are also involved in the project are producing implants made of magnesium alloys through the use of Selective Laser Melting (SLM). To ensure the safety of the novel composite materials from the outset, colleagues from IGB in the "DegraLast" project are establishing cell-based in-vitro test systems for analysis of the ingrowth behavior in the bone. The scientists at IBMT are in turn working on an in-vivo monitoring system that can monitor and document the degradation behavior of the implants in the human body.



The demonstrator for a suture anchor made of iron-tricalcium phosphate (FE-TCP) is only slightly larger than a match head. (© Fraunhofer IFAM) | Picture in color and printing quality: www.fraunhofer.de/press

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Health screening for industrial machines

RESEARCH NEWS
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Metal forming machines have to withstand considerable forces and yet remain in operation for a long time. When cold forming parts for automobiles, washing machines, refrigerators and the like, the exerted pressure can easily amount to several thousand metric tons. This operation has to be repeated hundreds of thousands of times in the complete lifetime of a machine. If the machine fails, it can cause substantial damage. Worse still, because the machine is usually integrated in a series of production steps, the failure can cause the entire production process to come to a stand-still. Depending on the extent of the damage, the repairs could take up to a month – accompanied by a loss of revenues in the six-digit region. If it were possible to predict such failures, either of the entire machine or a single component, companies would know precisely when they ought to maintain the machine or replace specific components, preferably in coordination with the production schedule.

Virtual sensors render real sensors almost obsolete

Researchers at the Fraunhofer Institute for Machine Tools and Forming Technology IWU in Chemnitz aim to change this situation. In the future, the machines themselves will be capable of detecting problems and predicting failures. As part of the EU-sponsored iMAIN project (www.imain-project.eu), the scientists have developed a prototype of an information-based predictive maintenance system that enables operators to determine when a component or entire plant is likely to fail. The distinctive feature of this technology is its use of virtual sensors. These receive input both from computer-simulated models of the machine and from real sensors that provide information on the strain occurring in individual components. "Using mathematical models and a minimum of actually installed, real sensors, it is possible to realistically simulate strain scenarios for the entire machine in real time. This in turn provides the basis for an entirely new and innovative approach to predictive maintenance," says Markus Wabner of Fraunhofer IWU.

Until now, it has been customary to carry out plant maintenance according to a fixed schedule or on an ad-hoc basis in response to failures. Certain manufacturers already equip their machines with (real) sensors, but solutions that rely exclusively on these devices are not ideal: they are expensive and complicated to implement, require their own error monitoring system, and measure stress and strain only at the points where they are installed – and nowhere else. "In our option, the use of virtual sensors is the only conceivable and economical way to obtain a complete picture of the forces acting on the material," says Wabner. While algorithms, simulations and mathematical models can often provide a reasonably good image of reality, even the most precise calculations are subject to errors. This is why the researchers constantly compare the virtual data with real measurements recorded while the machine is in operation. "If there is a wide discrepancy between them, we modify the model accordingly," says Wabner.

A cloud site accessible to internal users via a wide range of interfaces – including smartphones, tablets and laptops – serves as storage of information on the stress history of different manufacturing plants. “The more data we collect, the easier it is to know the right time to implement preventive measures. We develop algorithms that enable machines to learn from experience, and decide on the right time to replace components or determine when they have reached their optimum stress loading. The real data are compared with a simulated model that can be used to calculate the breaking point of the material,” explains Wabner.

The EU-sponsored iMAIN project was launched in September 2012 and brings together manufacturers, industrial users, computer scientists and engineers in a concerted effort to develop new, advanced technologies for the maintenance of industrial machines. “The virtual sensors have long since passed the proof-of-concept stage and are already being successfully used in real-life applications. And the private cloud solution for data sharing has reached the test stage,” reports Wabner. A prototype version of the system is being used by a project partner in Slovenia - the Gorenje Group, which manufactures home appliances – for the condition monitoring of a universal press supplied by Litostroj Ravne, another project partner. This factory forms metal panels used in the construction of washing machines, refrigerators and other appliances. “Since this system was introduced, Gorenje has better information enabling it to predict possible outages in advance, and also facilitate and optimize press operations by monitoring the stress and strain on the machines. We regularly compare the recorded data with the results of tests conducted at our facility at Fraunhofer IWU,” says Wabner. The ultimate aim is to be able to produce a system capable of predicting the stress-related failure of components in practice by the time the project ends next summer.

Trained workers at Gorenje install sensors in the tool components of a press used to produce parts for household appliances. (© Gorenje Group) | Picture in color and printing quality: www.fraunhofer.de/press

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Fraunhofer

Versatile bonding for lightweight components

RESEARCH NEWS
11 | 2014 || Topic 5

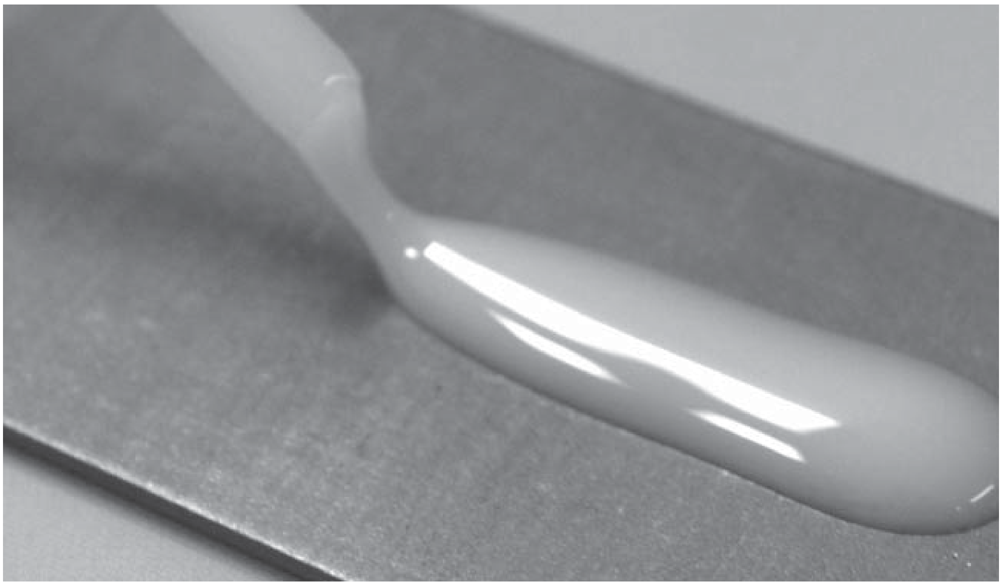
Shedding pounds is all the rage these days and the global trend toward weight reduction has even spread to the automobile industry. Cars are to get even lighter – using new materials such as ultra-high-strength steels or carbon, and carbon-fiber-reinforced plastics (CFRP). But no matter which diet regime and which lightweight components manufacturers choose, they all want the same thing: the best and longest-lasting joining method for vehicle components. Since Duroplast, which often serves as the matrix component for CFRPs, can't be welded, another joining technique is called for.

Bonding is the best solution. "We work primarily with structural adhesives, which bond components permanently and create additional shape stability," says Dr.-Ing. Jan Spengler, a chemical analyst in the Plastics division at the Fraunhofer Institute for Structural Durability and Reliability LBF in Darmstadt. These adhesive bonds offer a particular advantage; they hold up considerably better in crashes than other types of bonds. What's more, adhesives possess better damping characteristics than metal and improve noise vibration harshness (NVH). NVH is the term for what car occupants perceive as vibration or hear as noise. "The adhesive layer functions like a classic damper, which saves on insulation material and reduces weight," says Dr.-Ing. Halvar Schmidt from the LBF's Structural Durability division.

Rigid and elastic at the same time

Both the Plastics and Structural Durability divisions at the LBF have been researching dual cure adhesives for the past year and a half. What makes them special is that they harden in two phases. For gradient adhesives like these, humidity, heat, anaerobic conditions or UV light trigger the first stage of the hardening process. Another activator can be used to initiate a secondary hardening process. "This kind of adhesive has been available on the market for some time, but up to now the products have always provided a constant elasticity and the same rigidity at every point," reports Spengler. "We've succeeded in manufacturing an innovative dual-cure adhesive with variable elasticity." The first heat-triggered hardening mechanism coats the entire adhesive surface, resulting in a soft, flexible product. A second hardening process begins when it is exposed to UV light. What makes it special is that this reaction can be contained to very specific areas. The adhesive's polymer chains crosslink where it is exposed to UV light, creating a localized area with greater rigidity. In this way, the LBF researchers have produced a bonded plastic with one very soft and one very hard half.

Thanks to the gradient rigidity, the innovative adhesive can achieve a significantly prolonged bond. This is important, considering that every trip a vehicle makes subjects the car to vibration loads, and such external stress is always distributed unevenly across the bond. What then happens is that joints develop stress peaks at the edges, and the bond is highly stressed. "Our newly developed adhesive with gradient rigidity is elastic on the outer edges and handles stresses better and stress peaks are absorbed," explains Spengler. "But in the middle, the adhesive layer has been spot-cured and is correspondingly rigid, which ensures that the bond and the adhered vehicle chassis maintain continuous shape stability.



The variable elasticity offered by dual-cure adhesives provides significantly longer-lasting adhesive bonds. (© Fraunhofer LBF) | Picture in color and printing quality: www.fraunhofer.de/press

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Fraunhofer

A coating that protects against heat and oxidation

RESEARCH NEWS
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Gases don't conduct heat as well as solids do. Cellular or aerated concretes take advantage of this effect, which experts call "gas-phase insulation". The heat barrier is achieved by air encased in the cavities of the concrete. But gas-phase insulation has far greater potential than keeping our homes warm. It can also be used to protect turbine engine and waste incinerator components when subjected to intense heat. All you need to do is transfer this effect to a coating that is just a few hundred micrometers thick.

Temperature differences of over 400 degrees Celsius

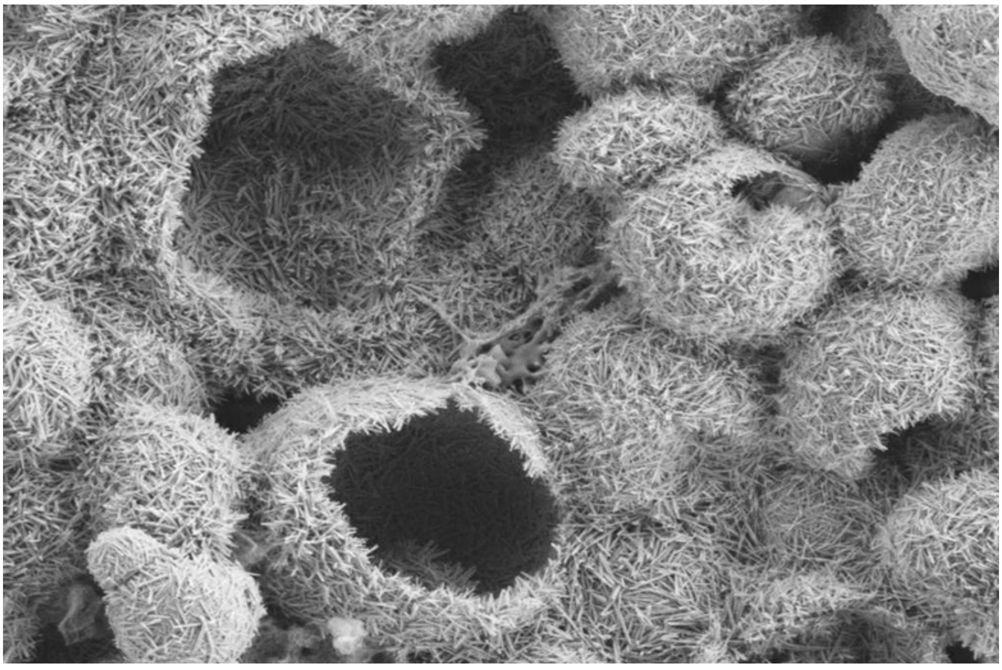
Scientists at the Fraunhofer Institute for Chemical Technology ICT in Pfinztal have not only done just that, they've also done it in a particularly economical way. They've designed a coating that consists of an outer topcoat from conjoined aluminium oxide spheres. "These spheres are hollow and filled with gas," explains coatings expert Dr. Vladislav Kolarik from the ICT's Energetic Systems department. When the outer side of a part is exposed to temperatures of 1000 degrees Celsius, these gas-filled spheres reduce temperatures on the part's inner side to under 600 degrees Celsius – as the ICT scientists have demonstrated in their laboratories. Since gas and steam turbines used for energy generation, combustion chambers, waste incinerator generators and temperature sensors, and reactors in the chemical and petrochemical industries are all subjected to temperatures of up to 1000 degrees Celsius, there is considerable demand of thermal protection.

What's most remarkable is that the heat insulating layer from hollow aluminium oxide spheres is obtained on the basis of a conventional, economic process. Operators only have to do some simple math to see the benefits: conventional thermal barrier techniques – most of which are based on ceramic materials – are expensive. The process the scientists adapted was originally designed to protect metallic components from oxidation. "We've optimized the technique so that the coat not only retains its oxidation protection, but furthermore protects against heat," says Dr. Kolarik. The basic coating layer forms by interaction of aluminum particles and the metallic component. This is done by depositing aluminum powder on the surface of the metal and heating it all up to a suitable temperature over several hours. The result is an aluminum-rich coating on the component's surface that protects against oxidation at high temperature. With the new procedure the topcoat from the hollow aluminum oxide spheres is additionally formed. "Up to now, it never occurred to anyone to use these spheres to produce another coating layer – they were just a waste product," says Dr. Kolarik.

Now the scientists have refined the process so they can produce both coating layers in the required thickness. The way it works is to take aluminum particles and mix them with a viscous liquid bonding agent. This produces a substance similar to a paint or slurry, which the scientists then manually paint, spray or brush onto the metallic component. "All that's left is to add a fair bit of heat," says Dr. Kolarik. But it's all easier said than done: Dr. Kolarik and his team have had to precisely fine tune the size and size distribution of the aluminum particles, the temperature and duration of the heating stage and the viscosity of bonding agents. "Just like a master chef, the first job was to come up with a winning recipe."

"We're currently in the process of putting the findings from the EU-funded PARTICOAT project into practice. This involves coating bigger and bigger components without exceeding the temperature limits for each application area. At the same time we're trying out techniques to automate the whole coating process. Our plan is to follow in the footsteps of the aerated concrete that helps insulate our homes – that's been in series production for a long time now," says Dr. Kolarik.

More information:
http://www.particoat.eu



Hollow spheres of aluminum oxide are filled with gas. Scientists have developed an economical way of manufacturing these insulators. (© Fraunhofer ICT) | Picture in color and printing quality: www.fraunhofer.de/press

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