

RESEARCH NEWS

07 | 2015 ||

1 Miniature pump regulates internal ocular pressure

Elevated or diminished eye pressure impairs our ability to see, and in the worst cases, can even lead to blindness. Until now, there has been no effective long-term treatment. In response, Fraunhofer researchers are developing an implantable microfluid system that can efficiently and durably stabilize intraocular pressure.

2 Revealing faded frescos

Many details of the wall and ceiling frescos in the cloister of Brandenburg Cathedral have faded: Plaster on which horses once “galloped” appears more or less bare. A hyperspectral camera sees images that remain hidden to the human eye, however, and is thus a big help for art historians.

3 Fuel and chemicals from steel plant exhaust gases

Carbon monoxide-rich exhaust gases from steel plants are only being reclaimed to a minor extent as power or heat. Fraunhofer researchers have developed a new recycling process for this materially unused carbon resource: They successfully produced fuel and specialty chemicals from these exhaust gases on a laboratory scale.

4 New research platform provides support to journalists

In-depth research is the key to all good journalism – but even experienced journalists have trouble dealing with the huge quantities of information available nowadays. A novel research platform promises to help editors obtain a rapid but thorough overview of material on a given subject.

5 Radar guards against space debris

Space debris poses a growing threat to satellites and other spacecraft, which could be damaged in the event of a collision. A new German space surveillance system, scheduled to go into operation in 2018, will help to prevent such incidents. The tracking radar is being developed by Fraunhofer researchers on behalf of DLR Space Administration.

6 Metal encapsulation optimizes chemical reactions

The chemical industry consumes millions of tons of packing materials as catalytic support media or adsorbents in fixed-bed reactors and heat storage systems. Fraunhofer researchers have developed a means of encapsulating these filler particles in metal that multiplies their thermal conductivity by five.

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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Miniature pump regulates internal ocular pressure

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Glaucoma and phthisis bulbi are incurable, insidious diseases of the eye. While glaucoma impairs the normal effluence of internal eye fluids, thereby elevating intraocular pressure, phthisis bulbi refers to a condition in which the eye produces too little vitreous humor. The eye begins to collapse upon itself: this is why it is sometimes referred to as atrophy of the eyeball. In either situation, the affected patient may experience severely impaired vision and possibly even blindness. Contemporary treatment approaches definitely attenuate disease progression, nonetheless they are effective for only a certain period. In glaucoma, for example, a surgeon creates an additional, artificial effluence from inside the anterior ocular chamber. The problem: in about one out of every four patients, scarring occurs after the procedure that impedes drainage of intraocular fluid. By contrast, in phthisis cases, the physician injects fluids like hyaluronic acid into the eye at regular intervals - an unpleasant procedure that still cannot prevent blindness in the immediate or distant future.

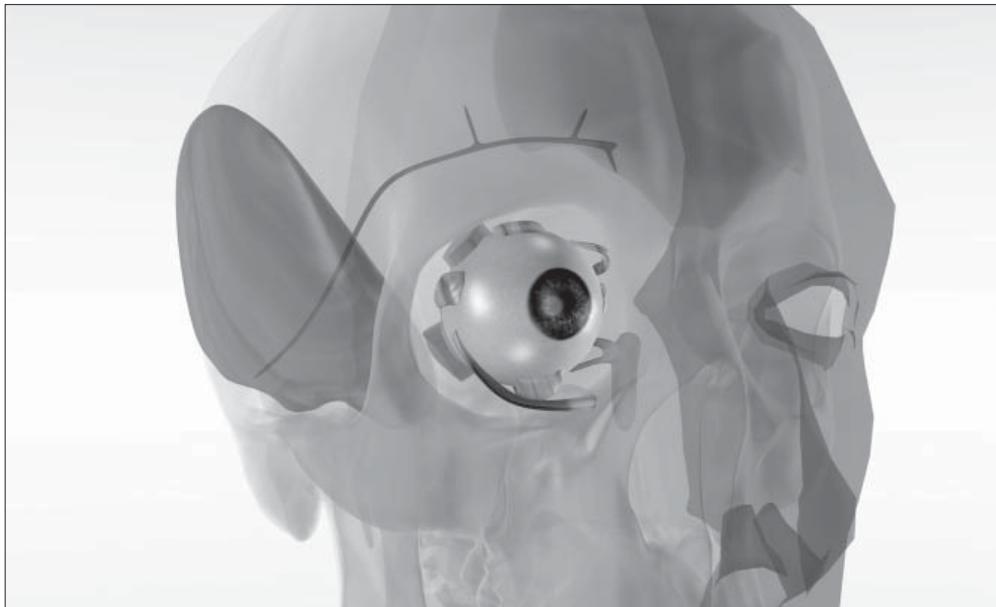
Researchers at the Fraunhofer Research Institution for Microsystems and Modular Solid State Technologies EMFT are working on a new approach to therapy: working jointly with several SMEs, they are engineering an active implant that is intended to efficiently and sustainably regulate eye pressure under the aegis of the MICROAUG project, under the KMU Innovativ Program sponsored by the federal ministry for education and research (BMBF). Geuder AG is spearheading the plan. "This way, we can spare the patient from the strain of multiple follow-up procedures, and can preserve the ability to see over a longer timeframe and, in the best case scenario, completely prevent blindness," says Christoph Jenke, Project Manager at EMFT.

Implants are applied to the eyeball.

The implant consists of a micro-pump system, a sensor-based pump control, an integrated battery for solid state energy supply as well as a telemetry module for data transmission. It can be attached directly to the eyeball: "Naturally, the patient should not sense it and his or her eye movements must not be restricted in any way," Jenke clarifies. The system components therefore had to be miniaturized. The Munich-based researchers developed a tiny (just 7x7x1 cubic millimeters), biocompatible silicon micro-membrane pump with a production rate of 30 microliters per second (maximum). Depending on the disease, it can moisturize the eye or drain intraocular fluid. Fraunhofer experts use the eye's natural drainage pathways so that no scar tissue forms. Monitoring at regular intervals, based on a conventional eye pressure measurement, the attending physician can set the volume of fluid to the desired level on an outpatient basis. In the long term, plans call for combining the system with an implantable sensor, so that fluids can be regulated automatically.

Not only is this new treatment approach gentler on the patient, it also offers added advantages: eye pressure can be set at a considerably more precise level than with pharmaceutical-based therapies or surgical intervention. Until now, phthisis bulbi inevitably led to blindness, and on top of this, the eye was typically removed for cosmetic reasons. "Since the absence of vitreous humor production is the exclusive cause of the disease in phthisis, we are optimistic that we can stop the disease progression and be able to preserve the eyesight sustainably," explains Jenke. "Our implant imitates a healthy eye's natural production of cameral fluid."

Currently, the partners are building a functioning demo model that meets all quality specifications with respect to space, energy management, pump control and micro-fluid management on the laboratory scale. Additional reliability and lifecycle testing are pending. Another job item is the hermetically sealed emplacement of the micro-pump chip onto the implant's titanium housing.



Cross-section of the eye with the implant. (© Fraunhofer EMFT) | Picture in color and printing quality: www.fraunhofer.de/press

Revealing faded frescos

The ravages of time have severely damaged the wall and ceiling frescos in the upper cloister of Brandenburg Cathedral (Brandenburg an der Havel). Much is no longer discernible with the naked eye. Often only fragments of what were once women with elegant garments and headgear standing together can be seen today. No matter how long one looks, images are undiscernible from the traces of pigments. A hyperspectral camera captures quite a different image with software developed by researchers from the Fraunhofer Institute for Factory Operation and Automation IFF in Magdeburg: It is bringing many of these faded frescos to light again.

Over Fifty Color Channels Detect the “Invisible”

The camera “looks” not only at the visible light reflected by the frescos – just as the eye or a conventional camera does – but also at the wavelengths in the infrared range. Moreover, its resolution is significantly finer. “Whereas humans assemble every perceived hue out of the colors red, green and blue, the camera has fifty-one color channels,” explains Dr. Andreas Herzog, a researcher at the Fraunhofer IFF. “It is therefore capable of distinguishing hues that appear identical to the human eye.” Where only blue is visible, for instance, the system divides the reflected light into the minimum of different hues, thus detecting structures that are actually no longer visible. This new technology additionally helps determine whether pictures were painted in several stages or have been restored at one time. Even if the paints might have looked the same to the artist, they could never have been mixed fully identically. The camera uncovers the differences.

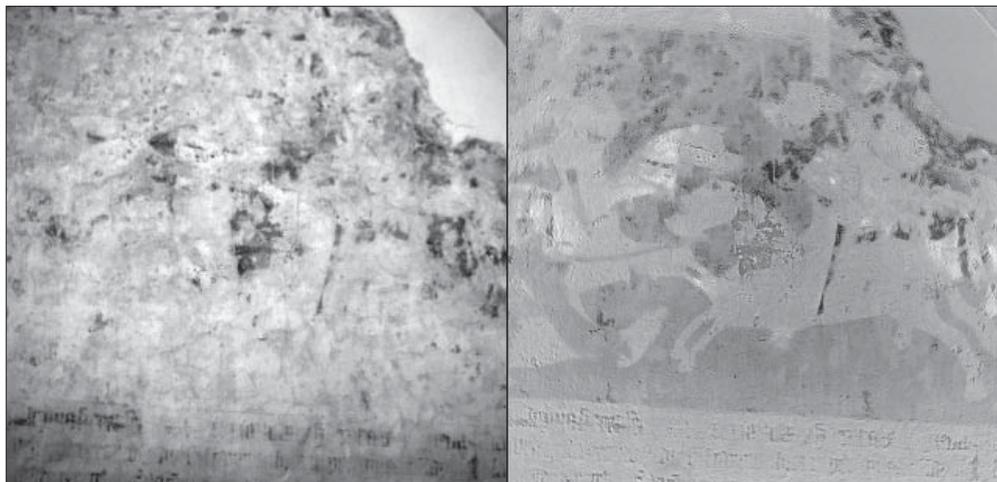
Some methods for detecting works of art exist already. Illuminating them with a UV lamp causes some substances in pigments, often the binder, to fluoresce. Using a conventional camera to capture their fluorescence also reveals hidden structures. The drawback is that the procedure is very involved and the UV light affects the paintings. This is not the case with the hyperspectral camera. It works with a normal light source that has less of an effect on works of art. What is more, the two procedures can be combined: The hyperspectral camera can also retrieve more out of the fluorescent light because it not only sees the light itself but also ascertains the composition of the fluorescing pigments.

Rather than the camera, the specially developed software is the centerpiece of this development. It uses the data produced during hyperspectral imaging to compile around one hundred images on some of which structures such as painted figures of women or horses come to light. Art experts examine and interpret these images. What mixture of pigments appears most frequently in the image selected? The algorithm computes this with the aid of statistics and standardization. It displays the proportion of exactly these pigment components in a separate image. The software algorithm proceeds in exactly

the same way with the second most frequent pigment components in a second image and so forth. The researchers are collaborating with surveyors at bgis Kreative Ingenieure GmbH in order to map large frescos on curved walls in high resolution, too. Their software assembles the individually computed images into one complete panorama and provides the art historians at the Cathedral Museum and Brandenburg State Cultural Heritage Preservation Agency an overview of larger correlations between images.

First Trial in Brandenburg Cathedral

The researchers from the Fraunhofer IFF have already tested their technology successfully in the upper cloister of Brandenburg Cathedral, which is celebrating its 850th anniversary this year: The art-historically significant wall frescos there were described in detail by Hartmut Schedel in the 15th century but were long thought to be lost until they were rediscovered a few years ago and then painstakingly restored. The cloister's secret has thus been revealed and, with the hyperspectral camera, even a large number of other details, too, little by little.



The upper cloister of Brandenburg Cathedral: Details of the wall frescos such as horses are now coming to light in spots where only traces of pigments had been discernible (left). A hyperspectral camera with specially engineered software has revealed the images (right). (© Fraunhofer IFF) | Picture in color and printing quality: www.fraunhofer.de/press

Fuel and chemicals from steel plant exhaust gases

RESEARCH NEWS

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The exhaust gas masses that arise from steel manufacturing plants are gigantic: the chimneys of the Duisburg Stahlwerke alone unleash several million tons of carbon dioxide. Fraunhofer has developed a process by which these exhaust fumes can be reclaimed and recycled into fuels and specialty chemicals. With the aid of genetically modified bacterial strains, the research team ferments the gas into alcohols and acetone, convert both substances catalytically into a kind of intermediary diesel product, and from this they produce kerosene and special chemicals. Participants include the Fraunhofer Institute for Molecular Biology and Applied Ecology IME in Aachen, as well as the Institute for Environment, Safety, and Energy Technology UMSICHT in Oberhausen and the Institute for Chemical Technology ICT in Pfinztal. The technology came about during one of Fraunhofer's internal preliminary research projects and through individual projects with industrial partners. The patented process currently operates on the laboratory scale.

Business model instead of problem

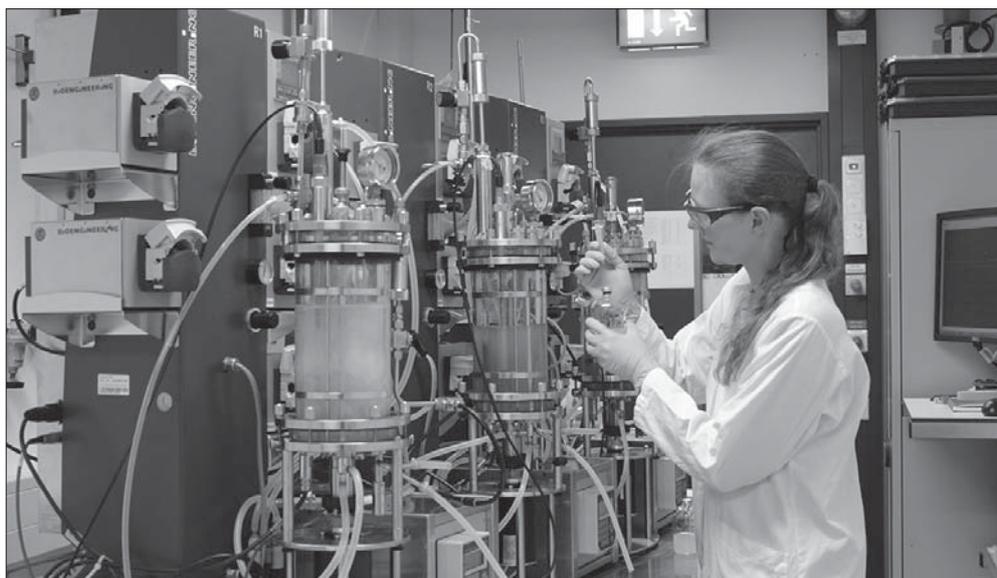
"From our viewpoint, the quantities of carbon alone – which rise as smoke from the Duisburg steelworks as carbon dioxide – would suffice to cover the entire need for kerosene of a major airline. Of course, we still have got a bit to go to reach this vision. But we have demonstrated on the laboratory scale that this concept works and could be of interest commercially. In addition to the exhaust gases, syngas – similar gas mixtures from home and industrial waste incineration – can also be used for the engineered process," explains Stefan Jennewein of IME, who is coordinating the project.

The biochemists at IME use syngas – a mixture of carbon monoxide, carbon dioxide and hydrogen – as a carbon resource for fermentation. Using bacterial strains of the *Clostridium* species, the syngas transforms either into short-chain alcohols like butanol and hexanol, or into acetone. To do so, IME engineered new genetic processes for the efficient integration of large gene clusters in the *Clostridium* genome. At the same time, Fraunhofer further expanded its syngas fermentation system and used it for experiments with the steel and chemicals industry.

The chemists around Axel Kraft at UMSICHT evaporate the residual fermentation products and in a continuous catalytic process, couple the fermentation molecules into an intermediate product consisting of long-chain alcohols and ketones. This interim product already meets the standards for ship diesel, and, like fats and oils, can be converted through hydrogenation into diesel fuel for cars or kerosene for planes. Kristian Kowollik from the environmental engineering department at ICT obtains specialty chemicals from the interim product connected with this, which already can now directly replace petroleum-based products. For example, amines can be used in the pharmaceutical industry or the production of tensides and dyeing agents. "The products syntheti-

cally produced by us can be used both as fuels as well as speciality chemicals. Exactly like this has worked until now with petroleum as the raw material source," states Jennewein.

In the next stage, the scientists strive to demonstrate that their technology also works with large quantities. "Over the next one-and-a-half years, we aim at gaining a better understanding of the processes, and to optimize them. Our goal is to apply for certification processes for the fuels. That is how its viability for practical use will be officially validated. For vehicle diesel, that takes about one year, and for kerosene about three years," Axel Kraft adds.



Fraunhofer is producing alcohol and acetone at its fermentation facilities, using the synthesized gas from the steel plants. Fuels and specialty chemicals can be procured from these.
(© Fraunhofer IME) | Picture in color and printing quality: www.fraunhofer.de/press

New research platform provides support to journalists

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An important summit meeting about the debt crisis in Greece has just come to an end, and any minute now the participants will emerge to face the press. Has Athens presented a list of reform proposals, and if so what are its central points? Have there been any statements by leading representatives of the German government and business community? How are the financial markets responding? And what's the mood among the general populace? It isn't easy to keep tabs on a situation like this and not miss out on any information. Every reporter worth their salt will take the investigation seriously, consulting endless different sources – from press conferences, news tickers and live video streams to commentaries posted on the social networks and the latest tweets. This mass of information is so huge that it is barely manageable without recourse to smart data analysis technologies. While solutions do exist in the form of analysis tools that search through news databases on the basis of semantic matching algorithms – and undoubtedly simplify the journalist's work – these are nothing more than island solutions according to Dr. Daniel Stein of the Fraunhofer Institute for Intelligent Analysis and Information Systems IAIS. He explains, "Because they are tailored to specific formats, they provide only a partial view of the complete news stream."

BMBF-funded project "News-Stream 3.0"

As part of the "News-Stream 3.0" project funded by the German Federal Ministry of Education and Research (BMBF), the Fraunhofer Institute in St. Augustin has joined forces with Neofonie GmbH, Deutsche Welle and the German Press Agency dpa to develop a novel analysis tool for journalists. As Dr. Stein explains, "Our aim is to create a research platform capable of processing heterogeneous, multimedia data streams rapidly and efficiently, performing a semantic analysis, pooling the results, and presenting a condensed overview in a uniform format." The new analysis process can scan information from different sources, including text messages, videos and audio files, in a matter of seconds. "It is an amalgam of existing approaches and product-ready solutions, blended together to create new tools," says Stein. With the help of the new technology, journalists and editors will soon be able to gather together the information they need to report on a specific subject and document the results of their research in what are known as "news cases". The content is continuously updated to ensure that users always stay abreast of the latest information.

One of the most important areas of expertise that the Fraunhofer scientists have brought to the project is that of audio analysis. The audio mining technology developed by Fraunhofer IAIS enables the spoken word in audio and video recordings to be analyzed in the same way as the content of text files. Their solution also takes voice recognition a step further by automatically identifying the person speaking. This technology is based on the i-vector paradigm that assigns an acoustic signature to each sound bite. The storage capacity of each i-vector is such that they are capable of analyzing even

large, heterogeneous, high-bitrate-streaming audio files in a minimum of time. Among other things, the speaker recognition function implemented in the News Stream platform is designed to ensure that editors don't miss a single statement by important personalities. For example, whenever the German chancellor appears before the camera to speak about an issue of topical interest, a reference to this broadcast is shown on the platform user's screen. This audio-based search function allows spoken-word content in the news streams to be linked with the name of the person speaking and filtered on this basis.

Deutsche Welle and dpa employees have recently started testing an early prototype in their daily work. "This user feedback is a crucial element of the project because it enables us to make further improvements to the platform while it is still at the development stage and thus ensure it meets the requirements of future users," says Stein.



Simultaneous speaker recognition and tweet analysis (example taken from the 2015 UK general election). (© Fraunhofer IAIS) | Picture in color and printing quality: www.fraunhofer.de/press

Radar guards against space debris

RESEARCH NEWS

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Traffic congestion is also an issue in space where, in addition to the dense network of satellites, orbiting space debris is increasingly transforming the paths on which they travel into a junkyard populated with burnt-out rocket stages and fragments of disintegrated spacecraft. Scientists estimate that there are now some 20,000 particles of space junk measuring more than ten centimeters in diameter hurtling around Earth at an average velocity of 25,000 kilometers per hour, not counting the 700,000 or so particles with a diameter of between one and ten centimeters. Although small, these items of space debris are traveling so fast that they could easily damage or destroy an operational satellite. The situation is exacerbated by the fact that space debris has a tendency to multiply exponentially through a kind of snowball effect. Whenever two particles collide, they break up into a greater number of smaller particles. Unless preventive measures are taken, the rapid multiplication of space debris could soon put an end to spaceflight as we know it.

There is urgent need for action. The Space Administration division of the German Aerospace Center (DLR) has been tasked by the German government with designing the German space program. In turn, DLR Space Administration has awarded a contract to the Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR in Wachtberg to develop and build a radar system for monitoring and tracking objects in low-Earth orbit. This is the region of space in which the risk of collisions is at its greatest – especially at an altitude of 800 kilometers above Earth. The German Federal Ministry for Economic Affairs and Energy (BMWi) has granted a total of 25 million euros to finance the GESTRA (German Experimental Space Surveillance and Tracking Radar) project over a four-year period.

“Whether we realize it or not, we all depend on space-based navigation, communication and Earth observation services – they are part of our social, political and industrial infrastructure. In order to protect these satellites from danger, we need to know what’s happening up there in space,” says Dr. Andreas Brenner, department head and deputy director of Fraunhofer FHR. With GESTRA, it will be possible to gather data on the trajectory of satellites and space debris orbiting Earth at altitudes of between 300 and 3000 kilometers. One of the chief purposes of the experimental radar is to provide advanced warning of possible collisions, and also to trigger an alarm when objects leave their orbit and reenter Earth’s atmosphere.

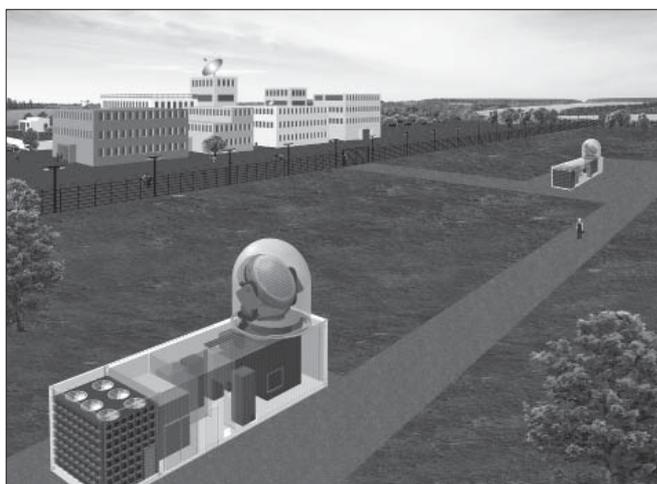
Electronically controlled, rapidly movable antenna

The FHR researchers are no newcomers when it comes to building radar systems. Their TIRA (Tracking and Imaging Radar) system is already being used to track objects in space. “TIRA collects high-definition images of individual objects using a mechanically controlled, movable antenna. The novel feature of the new GESTRA system is that its

antenna is electronically controlled, and can therefore be reoriented even faster because it has no heavy moving parts. Unlike TIRA, it is capable of observing a very large number of objects simultaneously while still supplying data of high accuracy and sensitivity," says Brenner.

A team of twenty researchers is responsible for building both the transmission and reception components of the transceiver system. Each of these sensing components consists of a phased-array antenna operating at a frequency of 1.3 GHz and made up of numerous individual antenna elements. This array antenna is equipped with high-performance processors that enable it to capture radar signals emitted by satellites and space debris in several cardinal directions simultaneously, in a fraction of a second. It can look in many directions at once and cover a very large area of the sky. "In tracking mode, we can follow the path of selected, individual objects. The computer-assisted, digital beamforming function allows the main beam to be set to a narrow width, enabling it to be focused on a single moving object. This could be compared with the cone of light produced by a pocket flashlight. Alternatively, the main beam can be extended in width to observe a broader section of the sky, allowing several pieces of debris to be tracked," Brenner explains.

Both the transmission and the reception units are fully retractable. This is an advantage because it allows the container in which the radar is housed, measuring 4 x 4 x 16 meters, to be transported from place to place. GESTRA will be operated by remote control from the German Space Situational Awareness Centre in Uedem, which is run jointly by the DLR and the German air force, while the radar itself will be installed at a different location. The space monitoring system is scheduled to start delivering data in 2018. The data from GESTRA will be made available to research institutions in Germany and form the basis for the development of future space surveillance systems.



Both the transmitting and receiving antennas are fully retractable. (© Fraunhofer FHR)
| Picture in color and printing quality: www.fraunhofer.de/press

Metal encapsulation optimizes chemical reactions

RESEARCH NEWS

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Random packing materials are used in many chemical reactors and heat storage systems as catalytic support media or adsorbents. Several million tons of these functional materials are consumed every year in industrial processes to produce chemical feedstock. To ensure that these processes produce the desired results, the packing materials have to be able to conduct heat efficiently. This is not always easy, because the gaps between the millimeter-scale particles prevent heat from being conducted optimally throughout the packed bed. Chemical companies therefore have to build special heat-conducting structures into their reactors. "This is time-consuming and expensive," says Jörg Adler, a researcher at the Fraunhofer Institute for Ceramic Technologies and Systems IKTS in Dresden. Together with colleagues at the Fraunhofer Institutes for Machine Tools and Forming Technology IWU in Chemnitz and for Interfacial Engineering and Biotechnology IGB in Stuttgart, Adler has developed a concept that increases the heat transfer capacity of the packing material fivefold. Their concept involves encapsulating cylindrical filler particles in metal. The points of contact between the metal-encapsulated particles form a metal framework that enables heat to be conducted throughout the packed bed faster and more efficiently.

Five times more efficient

The scientists have conducted tests in the laboratory that prove that this efficiency gain is realizable, using a heat storage system consisting of an eight-liter packed bed of aluminum-encapsulated zeolite pellets. Adler lists the advantages: "The packed bed is heated to an even temperature more rapidly. It takes significantly less time to load and unload the heat storage medium. This makes it possible to enhance the efficiency of chemical reactions and hence increase product quality." The researchers expect that it will be possible to obtain even better results using a metal with a higher thermal conductivity, such as copper. The particles of packing material used in the laboratory tests are five millimeters long and encapsulated in a layer of aluminum with a thickness of 0.25 millimeters. The scientists produce them using a specially developed process that could be easily adapted to mass production. The packing material is poured into long, thin metal tubes, compacted to prevent it from spilling out, and the tubes are then cut into sections to form cylindrical particles no more than a few millimeters in length.

"The chemical industry uses large quantities of packing materials which, ideally, are expected to remain in the reactors for many years. One of the problems is that they are subject to powder abrasion during shipping and when in use, caused by particles rubbing against one another. This no longer happens when they are encapsulated in metal, and so the packing material lasts longer," says Adler.

Applying heat to zeolite pellets that are saturated with water causes the pellets to dry and absorb heat. When the pellets are rehydrated, the absorbed heat is released. This

physical effect makes them suitable for use in heat storage systems. In this application too, says Adler, "the efficiency of the process depends on the thermal conductivity of the zeolite material. It is often necessary to install very complicated heat-exchanger units, which are expensive and reduce the volume available for actual heat storage. The metal-encapsulated packing material could be a valuable improvement here. In the laboratory, we have been able to significantly shorten the heat storage cycle time."

Now that the researchers have demonstrated the feasibility and functionality of the encapsulation technique in the lab, they want to move on to the next step on the way to industrial application. "We need to further optimize the material and the manufacturing process, and gather data so as to determine exactly to what extent the advantages of higher thermal conductivity outweigh the additional costs of metal encapsulation," says Adler.

The chemical industry uses large quantities of packing materials as catalytic support media and adsorbents. A catalyst is a substance that accelerates a chemical reaction without undergoing any chemical change itself. An adsorbent removes and stores specific products of a chemical reaction. As well as being used to optimize chemical reactions, packing materials also play a role in modern heat storage systems. In a packed bed reactor, a gas or liquid flows through the material and triggers a chemical reaction on the surface of the tiny particles.



The chemical industry uses large quantities of packing materials. To protect the millimeter-scale particles against abrasion, Fraunhofer IKTS encapsulates them in a layer of metal that boosts their thermal conductivity by a factor of five. (© Fraunhofer IKTS) | Picture in color and printing quality: www.fraunhofer.de/press