Fraunhofer

RESEARCH NEWS

10 | 2012 ||

1 Artificial cornea gives the gift of vision

Blindness is often caused by corneal diseases. The established treatment is a corneal transplant, but in many cases this is not possible and donor corneas are often hard to come by. In the future, an artificial cornea could make up for this deficiency and save the vision of those affected.

2 Solar cells made from black silicon

Solar cells convert three-quarters of the energy contained in the Sun's spectrum into electricity – yet the infrared spectrum is entirely lost in standard solar cells. In contrast, black silicon solar cells are specifically designed to absorb this part of the Sun's spectrum – and researchers have recently succeeded in doubling their overall efficiency.

3 Wireless data at top speed

Digital cameras and camcorders deliver high resolution film sequences that are several gigabytes in size. These can take several minutes to transfer wirelessly to your home computer via Bluetooth. Now there is a speedy alternative: the "multi-gigabit communication module" is six times faster than a USB cable.

4 Fast toothpaste check

There are various types of toothpaste available on the market. They come as pastes and gels, there are some that guard against tooth decay or protect teeth from acid attack, others that are designed for sensitive teeth. But which toothpastes clean well? Which preserve the tooth enamel? A new evaluation method sheds light on the subject.

5 Using less gas and oil to get where you're going

A quick pit-stop at the gas station is enough to put a good dent in your wallet. New technology is set to lower the high cost of filling up your car, by enabling combustion engines to consume two to three percent less gas and significantly less oil, while eliminating a step in engine production.

6 Lightning, strike!

Every year several millions of tons of building rubble are produced. An efficient way of recycling concrete – the building material of the 20th and 21st century – does not yet exist. Researchers are working on new recycling methods, and with the aid of lightning bolts, they can break down the mixture of cement and aggregate into its components.

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The Fraunhofer-Gesellschaft is the leading organization for applied research in Europe. Its research activities are conducted by 60 Fraunhofer Institutes at over 40 different locations throughout Germany. The Fraunhofer-Gesellschaft employs a staff of around 20,000, who work with an annual research budget totaling 1,8 billion euros. Roughly two thirds of this sum is generated through contract research on behalf of industry and publicly funded research projects. Branches in the USA and Asia serve to promote international cooperation.

Editorial Notes:

RESEARCH NEWS l Frequency: monthly l ISSN 09 48 - 83 83 | Published by Fraunhofer-Gesellschaft l Press Office l Hansastraße 27 l 80686 München l Phone +49 89 1205-1333 l presse@zv.fraunhofer.de | Editorial Staff: Franz Miller, Janine van Ackeren, Britta Widmann l Reprints free of charge.We encourage you to favor the online version and newsletter via www.fraunhofer.de/fhg/EN/press This bulletin is also available in German as FORSCHUNG KOMPAKT.

Artificial cornea gives the gift of vision

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Our eyes are our window to the world. Thousands of people have lost their eyesight due to damages to the cornea, such as trauma, absent limbal stem cells or diseases. Transplantation of a donor cornea is the therapy of choice for a great number of those patients. Let alone the issue of scarce donor material, a sub-group of patients do not tolerate transplanted corneas, necessitating the employment of an alternative means of restoring eye sight. In Germany alone, around 7,000 patients are waiting to be treated. In close cooperation with the Aachen Centre of Technology Transfer, Dr. Storsberg and his team from the Fraunhofer Institute for Applied Polymer research IAP in Potsdam, are attempting to improve the situation by developing an artificial cornea. Scientific partners in the "ART CORNEA" project include the Martin Luther University of Halle-Wittenberg, ACTO e. V. and the Ophthalmic Clinic Cologne-Merheim.

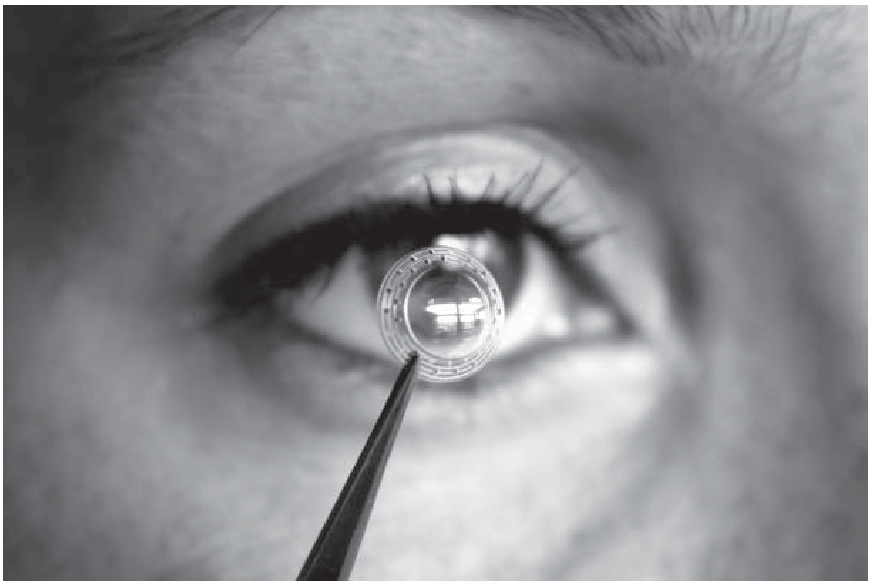
"We are in the process of developing two different types of artificial corneas. One of them can be used as an alternative to a donor cornea in cases where the patient would not tolerate a donor cornea, let alone the issue of donor material shortage," says IAP project manager Dr. Joachim Storsberg. The scientist has considerable expertise in developing and testing of next-generation biomaterials. Between 2005 and 2009 he collaborated with interdisciplinary teams and private companies to successfully develop an artificial cornea specifically for patients whose cornea had become clouded – a condition that is extremely difficult to treat. Such patients are unable to accept a donor cornea either due to their illness or because they have already been through several unsuccessful transplantation attempts. Dr. Storsberg was awarded the Josef-von-Fraunhofer Prize 2010 for this achievement. "A great many patients suffering from a range of conditions will be able to benefit from our new implant, which we've named ArtCornea®. We have already registered ArtCornea® as a trademark," reports Storsberg.

Ultima ratio patients regain vision

ArtCornea® is based on a polymer with high water-absorbent properties. Dr. Storsberg and his team have added a new surface coating to ensure anchorage in host tissue and functionality of the optic. The haptic edge was chemically altered to encourage local cell growth. These cells graft to the surrounding human tissue, which is essential for anchorage of the device in the host tissue. The researchers aimed to enlarge the optical surface area of the implant in order to improve light penetration beyond what had previously been possible – a tall order. "Once ArtCornea® is in place, it is hardly visible, except perhaps for a few stitches. It's also easy to implant and doesn't provoke any immune response," says Storsberg, highlighting the merits of this new development.

The specialists have also managed to make a chemically and biologically inert base material biologically compatible for the second artificial cornea, ACTO-TexKpro. Dr. Storsberg achieved this by selectively altering the base material, polyvinylidene difluoride, by coating the fluoride synthetic tissue with a reactive molecule. This allows the patient's cornea to bond together naturally with the edge of the implant, while the implant's inner optics, made of silicon, remain free of cells and clear. The ACTO-TexKpro is particularly suitable as a preliminary treatment, for instance if the cornea has been destroyed as a consequence of chronic inflammation, a serious accident, corrosion or burns.

The experiments were carried out in collaboration with Dr. Norbert Nass and Dr. Saadettin Sel, Senior consultant ophthalmologist at Martin-Luther-University Halle-Wittenberg. How well TexKpro and ArtCornea® are accepted by clinicians as an additional tool at their disposal was first tested by the doctors in the laboratory thereafter in vivo in several rabbits. After a six month healing process, the implanted prostheses were accepted by the rabbits without irritation, clearly and securely anchored within the eye. Tests carried out following the operation showed that the animals tolerated the artificial cornea well. Prof. Dr. Norbert Schrage will take charge of clinical trials that will soon commence at the Eye Clinic Cologne-Merheim. It is likely that the positive results of tests carried out thus far will be confirmed, and the co-operation partners rate the chances of success very highly. Their optimism is well founded: As early as 2009, several Ultima-Ratio patients received implants of a Kerato prosthesis specially developed for them because they had previously rejected human corneas. These patients have not suffered any complications and are still wearing their artificial corneas today.



ArtCornea® is easy to implant. This artificial cornea does not trigger any immune reactions. (© Fraunhofer IAP) | Picture in color and printing quality: www.fraunhofer.de/press

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Solar cells made from black silicon

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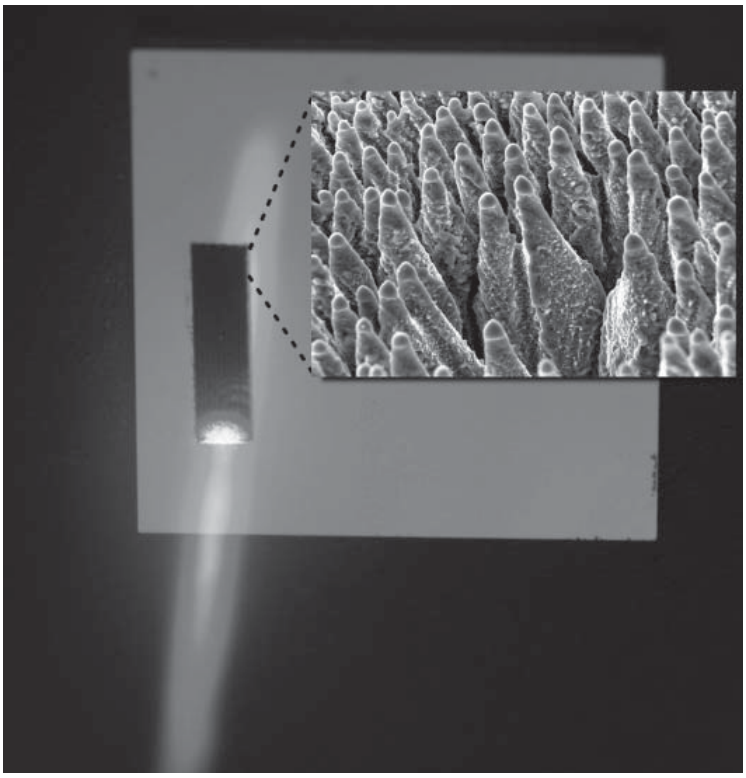
The Sun blazes down from a deep blue sky – and rooftop solar cells convert this solar energy into electricity. Not all of it, however: Around a quarter of the Sun's spectrum is made up of infrared radiation which cannot be converted by standard solar cells – so this heat radiation is lost. One way to overcome this is to use black silicon, a material that absorbs nearly all of the sunlight that hits it, including infrared radiation, and converts it into electricity. But how is this material produced? "Black silicon is produced by irradiating standard silicon with femtosecond laser pulses under a sulfur containing atmosphere," explains Dr. Stefan Kontermann, who heads the Research group "Nanomaterials for Energy Conversion" within the Fraunhofer Project Group for Fiber Optical Sensor Systems at the Fraunhofer Institute for Telecommunications, Heinrich-Hertz-Institut, HHI. "This structures the surface and integrates sulfur atoms into the silicon lattice, making the treated material appear black." If manufacturers were to equip their solar cells with this black silicon, it would significantly boost the cells' efficiency by enabling them to utilize the full Sun spectrum.

Researchers at HHI have now managed to double the efficiency of black silicon solar cells – in other words, they have created cells that can produce more electricity from the infrared spectrum. "We achieved that by modifying the shape of the laser pulse we use to irradiate the silicon," says Kontermann. This enabled the scientists to solve a key problem of black silicon: In normal silicon, infrared light does not have enough energy to excite the electrons into the conduction band and convert them into electricity, but the sulfur incorporated in black silicon forms a kind of intermediate level. You can compare this to climbing a wall: The first time you fail because the wall is too high, but the second time you succeed in two steps by using an intermediate level. However, in sulfur this intermediate level not only enables electrons to climb the 'wall', it also works in reverse, enabling electrons from the conduction band to jump back via this intermediate level, which causes electricity to be lost once again. By modifying the laser pulse that drives the sulfur atoms into the atomic lattice, researchers can change the positions that these atoms adopt in the lattice and change the height of their 'levels', in other words their energy level. "We used the laser pulses to alter the embedded sulfur in order to maximize the number of electrons that can climb up while minimizing the number that can go back down," Kontermann sums up.

Prize-winning project

In the first stage of the project, the scientists modified the laser pulses and investigated how this changed the properties of black silicon and the efficiency of solar cells made from this material. Now they are working on using different shapes of laser pulses and analyzing how this changes the energy level of the sulfur. In the future, they hope that a system of algorithms will automatically identify how the laser pulse should be modified in order to achieve optimum efficiency. The 'Customized light pulses' project was one of this year’s winners in the ‘365 Places in the Land of Ideas’ competition; the awards ceremony is due to be held in Goslar on October 11, 2012.

The researchers have already successfully built prototypes of black silicon solar cells and their next step will be to try and merge these cells with commercial technology. “We hope to be able to increase the efficiency of commercial solar cells – which currently stands at approximately 17 percent – by one percent by combining them with black silicon,” Kontermann says. Their starting point is a standard commercial solar cell: The experts simply remove the back cover and incorporate black silicon in part of the cell, thereby creating a tandem solar cell that contains both normal and black silicon. The researchers are also planning a spin-off: This will be used to market the laser system that manufacturers will be able to acquire to expand their existing solar cell production lines. Manufacturers would then be able to produce the black silicon themselves and include it in the cells as standard.



Black silicon is irradiated with a laser. Small image: Black silicon, magnified.
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Wireless data at top speed

RESEARCH NEWS
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Whether it's a wedding, birthday party or other celebration, these days the chances are you'll have your camcorder with you to record the great occasion. But we often forget to bring the data cable along with us, so despite promising the hosts to transfer the images to their computer the morning after, we hardly ever do. "No problem," we say, "I'll burn you a CD when I get home." It would be so much easier, though, to transfer the data wirelessly.

This thought also occurred to Frank Deicke, a researcher at the Fraunhofer Institute for Photonic Microsystems IPMS in Dresden. There just had to be a way to transfer large amounts of data quickly and easily from one device to another. Obviously, wireless connections like Bluetooth or Wi-Fi are now commonplace. But using them to copy high resolution video footage of an entire wedding reception to a computer takes a great deal of patience, as transferring several gigabytes of film data wirelessly can take several minutes. Deicke and his colleagues took a different approach. Deicke specializes in infrared technology and, a few weeks ago, the researcher presented an infrared module the like of which has never been seen before. "It transfers data at a rate of 1 gigabit per second (Gbit/s). To put this into context, one e-mail character has a size of eight bits. The infrared module is able to transfer 125 million characters per second," says Deicke.

Faster than USB2, Wi-Fi and Bluetooth

As a general rule, cable connections between electronic devices are faster than wireless ones. In this case it is the other way around. The new "multi-gigabit communication module" is six times faster than a USB2 cable. A comparison with established wireless standards is even more impressive. The IPMS solution is 46 times faster than conventional Wi-Fi and 1430 times faster than a Bluetooth connection, as used to connect cell phones and earphone headsets, for example. This performance is above all due to high-speed signal processing. In data transfer, the bottleneck is the encoding and decoding of the data, which is to say the packing and unpacking necessary to send data through the air. Before setting off, video information from the digital camera first has to be converted into a radio signal. The receiving device, a laptop for example, then decodes the radio signal and converts it back into film data. All this costs processing time.

The challenge for the researcher and his team was to build a small infrared module with fast-working hardware and software. In addition, the processing time required should be minimal, because the harder the microprocessors have to work, the more electricity they eat up. "We achieved this ultimately through a clever combination of different technical solutions," says Deicke. One of these is the transceiver, an optical component which is able to send and receive light signals simultaneously. The transceiver is only about the size of a child's fingernail, but manages to fit in a laser diode to send light pulses and a photo detector to detect them. The decoders that receive and translate the encoded data are also crucial. Deicke and his colleagues had to program ingenious error-correction mechanisms, because the light signals become weakened and distorted in the air. Just like controlling a TV with its remote, there has to be a clear line of sight between sender and receiver. This is no problem for Frank Deicke: "You simply place the camera or the smartphone next to the computer or laptop." The video is transferred in just a few seconds.

The IPMS researchers are very much aware that manufacturers have to accept such technology as standard before it can catch on. Only then will it find its way into a wide variety of devices, enabling consumers to connect almost any laptop to any camera without problems. This is why Deicke is active in the Infrared Data Association, where among other things he contributes to the "10 Giga-IR working group". This makes his goal for the future obvious: to improve on 1 Gbit per second. "Our current infrared module has already demonstrated that infrared technology is able to go far beyond established standards. We plan to improve performance even more in the future." Deicke has already been able to show that the transfer rate of his current model can be raised to 3 Gbits. 10 Gbits cannot be very far off.

This optical wireless communication module can achieve a transmission rate of 3 Gbit/s.
(© Fraunhofer IPMS/Jürgen Lösel) | Picture in color and printing quality: www.fraunhofer.de/press

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Fast toothpaste check

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Everyone wants to have beautiful teeth. After all, a perfect set of teeth symbolizes health and youthfulness, and can even influence career prospects. If having pristine teeth calls for thorough oral hygiene, then how well or badly does a given toothpaste clean? How effective is it? What should it contain in order not to damage the structure of the teeth? Such questions are primarily of interest to manufacturers of dental hygiene products, and answers are being delivered by researchers from the Fraunhofer Institute for Mechanics of Materials IWM in Halle. Through close collaboration with the Microtribology Centre µTC in Karlsruhe they have developed a new process for testing the abrasive effect of toothpastes, allowing this 'abrasivity', as experts call it, to be compared and evaluated in the lab.

Dangerous abrasive effect

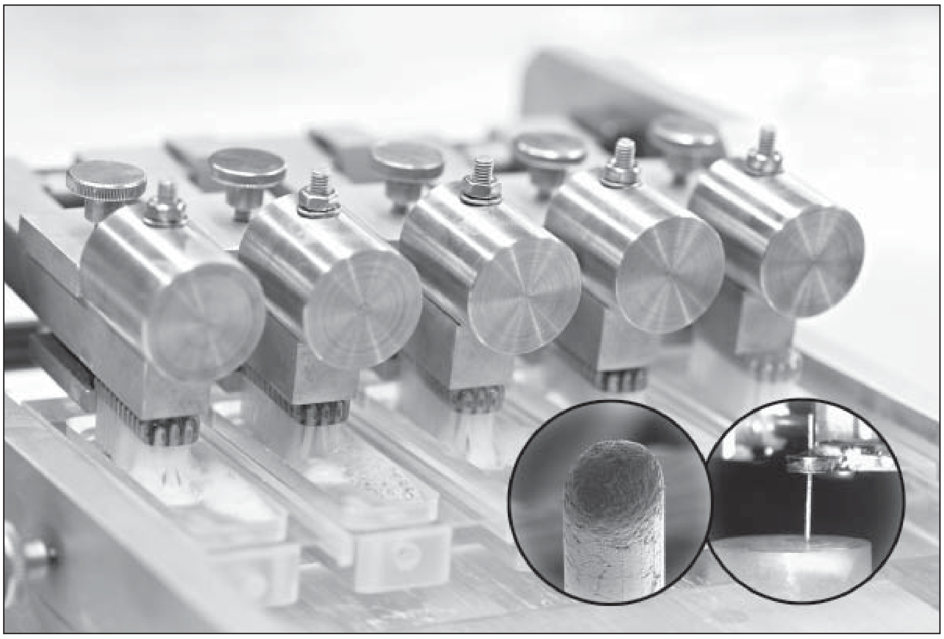
Cleaning particles are an important component of toothpastes. These abrasives, as they are known, mechanically remove dental plaque. Nevertheless, the paste should not be too strongly abrasive. Over the years the abrasion can cause damage to the tooth enamel, which does not regenerate itself. This damage is more visible and pronounced in the soft dentin. The German Dental Association recommends that people choose less abrasive toothpaste if the necks of their teeth are exposed.

The abrasive effect of a particular toothpaste on tooth dentin depends on the hardness, amount and particle size of the abrasive additives it contains, such as silica or alumina. Abrasivity is measured as the RDA value (radioactive dentin abrasion), ranging from 30 to over 200. This value is determined via a complex process that involves testers brushing over radioactively marked dentin samples. The abraded material is then measured via the resultant radiation intensity of the toothpaste slurry. Not all experts agree on the validity of RDA values, as test results have been known to vary partly from lab to lab.

Determining abrasion rates with microtribological tests

The researchers at the IWM have chosen an alternative method to this radiotracer system. "Our new approach enables us to determine realistic abrasion rates and characterize the interaction between brush, enamel and toothpaste. What's more, our tests are less laborious than the time-intensive radiotracer procedures carried out by only a handful of laboratories worldwide", says Dr. Andreas Kiesow, team leader at the IWM. The scientist and his team have successfully managed to determine the abrasion of various toothpastes on a microscopic scale and to measure the friction values using microtribological experiments. "Until now, tribological values such as friction coefficient, did not exist" says Kiesow.

The researchers use human teeth as well as different toothpastes made by industrial partners for their experiments. These toothpastes were diluted with water and saliva in order to create a solution whose consistency corresponds to the mixture of toothpaste and saliva that is present when people brush their teeth. The friction and wear tests were each carried out with a single bristle – referred to as a monofilament. This is mounted in specialized tribological instruments, a microtribometer and a nanoindenter, and moved over the sample in both straight and circular motions, in the latter case up to 8000 times. Highly sensitive instruments then measure the depth of the resultant marks left on the surface of the tooth. "Our findings reveal that the RDA value of toothpastes correlates with the depth of abrasion; the higher the value, the greater the abrasion. By analyzing the friction value we also identified a clear relationship between the friction behaviors of the bristle on the dental enamel and the abrasiveness of the toothpaste", sums up Kiesow. The new process allows the researchers to not only characterize the abrasion more quickly and simply, but also to describe how different geometries of toothbrush filaments act upon the surface of the tooth and how the bristle shape should ideally be designed. The experts at IWM can use their know how to support manufacturers of dental hygiene with product development. At the end of the day it is the consumer who benefits most.



Researchers intend to supplement their microtribological analyses of the interaction between toothbrush, toothpaste and tooth surface with practical tests, using a tooth cleaning machine they have developed themselves. Bottom right: Friction and wear tests with individual bristles. (© Fraunhofer IWM) | Picture in color and printing quality: www.fraunhofer.de/press

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Using less gas and oil to get where you're going

An engine without oil will not survive for very long. Pistons need plenty of lubricant in order to be able to move within the cylindrical sleeves in the engine block. Two things are known to raise the resultant level of friction. The first is attributed to distortion of the cylindrical bore hole when the cylinder head is attached, which is known as static distortion. The second occurs when the engine is running and temperatures warp the bore hole. The extent of this thermal distortion depends on prevailing engine temperatures and the specific engine model. In reality, the piston does not follow a perfectly smooth up and down motion, but instead touches at points within the bore hole. This results in the engine requiring a great deal more oil as well as more gas. Automakers are already able to compensate static distortion. During the final machining stage, honing, technicians mount a honing liner to the engine which simulates the cylinder head that will later be mounted. Only then the work on the bore hole is completed. Thermal distortion, on the other hand, presents difficulties since it has not been possible to compensate for this effect until now.

Saving two to three percent of fuel

This problem has now been solved by researchers at the Fraunhofer Institute for Machine Tools and Forming Technology IWU in collaboration with a car manufacturer and a machine tool producer. "Our technology makes it possible to compensate for both static and thermal distortion. This can lead to a fuel saving of two to three percent in combustion engines, and remove one step in their production," says IWU head of department André Bucht. This clever technology is based on a tool that can adapt its own shape. Researchers start by working out how an engine block is likely to become distorted: they determine the level of static distortion by unscrewing the cylinder head and measuring the extent to which the bore hole has been warped. They then simulate thermal distortion that occurs in each engine series, using an operating temperature of 90 degrees Celsius as their reference. The honing tool adjusts its shape based on these calculations, thereby altering the profile of the bore hole so that motions of the piston are perfectly smooth later on when the engine is running, preventing excessive friction. Researchers have integrated small Piezo actuators into the tool which alter its shape and expand the diameter as required. "This is how we can incorporate any 'imperfections' in the otherwise perfectly round shape of the finished bore hole," says Bucht.

A prototype of the tool already exists. The researchers have put it to use to prove that they can achieve the surface accuracy required without slowing down production – there being no more than 20 to 30 seconds for the assembly of each engine. Research is currently being performed on the test rig in collaboration with auto manufacturers. This is where an engine produced using the tool is put through its paces. Researchers are examining to what extent piston friction and fuel consumption are reduced, and how the lifespan of the engine might be affected in comparison with engines manufactured using conventional tools . The tests are scheduled to be completed by the end of the year. Researchers then plan to design the tool and the production process so that they can be adopted by manufacturers.

The honing tool adjusts its shape to match the piston bore holes. (© Fraunhofer IWU) | Picture in color and printing quality: www.fraunhofer.de/press

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Lightning, strike!

RESEARCH NEWS
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Whether the Pantheon in Rome or the German concrete canoe regatta, whether ultra-light or decorative: concrete is unbelievably versatile and is the world's most widely used material – next to water. It is made of cement, water and aggregate, a mixture of stone particles such as gravel or limestone grit in various sizes. However, the CO_2 emissions, which are mainly the result of cement production, are problematic: the production of one ton of burned cement clinker of limestone and clay releases 650 to 700 kilograms of carbon dioxide. This means that every year 8 to 15 percent of global CO_2 production is attributable to concrete manufacturing. And when it comes to recycling waste concrete, there is no ideal solution for closing the materials loop. In Germany alone the quantity of construction waste amounted to almost 130 million tons in 2010.

"This is an enormous material flow, but at the moment there is no effective recycling method for concrete rubble" explains Volker Thome from the Fraunhofer Institute for Building Physics IBP from the Concrete Technology Group in Holzkirchen. The current method is to shred the concrete, which produces huge amounts of dust. At best, the stone fragments end up as sub-base for roads. "This is downcycling," explains Thome, in other words, simply the reutilization of raw materials, the quality of which deteriorates from process to process. On the other hand, if it were possible to separate the stone particles from the cement stone, the gravel could easily be reused as an aggregate in new cement – a first decisive step in the direction of recycling waste concrete. "The recovery of valuable aggregate from waste concrete would multiply the recycling rate by a factor of around ten and thereby increase it to 80 percent," says Thome. If it were also possible to obtain a cement substitute from waste concrete, the cement industry's CO_2 emissions would be considerably reduced. To achieve these goals Thome revived a method that Russian scientists already developed in the 1940s then put on ice: electro-dynamic fragmentation. This method allows the concrete to be broken down into its individual components – aggregate and cement stone.

Recycling valuable components

Using this approach, the researchers in Holzkirchen are unleashing a veritable storm of lightning bolts. "Normally, lightening prefers to travel through air or water, not through solids," says Thomas. To ensure the bolt strikes and penetrates the concrete, the expert uses the Russian scientists' expertise. More than 70 years ago they discovered that the dieletric strength, i.e. the resistance of every fluid or solid to an electrical impulse, is not a physical constant, but changes with the duration of the lightning. "With an extremely short flash of lightning – less than 500 nanoseconds – water suddenly attains a greater dielectric strength than most solids," explains Thome. In simple terms, this means that if the concrete is under water and researchers generate a 150 nanosecond bolt of lightning the discharge runs preferably through the solid and not through the water.

“That is the essence of the method,” says Thome. In the concrete the lightning then runs along the path of least resistance which is the boundaries between the components, i.e. between the gravel and the cement stone. The initially generated impulses, the pre-discharges, first weaken the material mechanically. “The pre-discharge which reaches the counter-electrode in our fragmentation plant at first, then causes an electrical breakdown,” explains Thome. At this instant a plasma channel is formed in the concrete which grows within a thousandth of a second, like a pressure wave from the inside outwards.

“The force of this pressure wave is comparable with a small explosion,” says Thome. The concrete is torn apart and broken down into its basic components. With the laboratory fragmentation plant the researchers can currently process one ton of concrete waste per hour. “To work efficiently, our goal is a throughput rate of at least 20 tons per hour,” says Thome. In as little as two years’ time, an appropriate installation could be ready for market-launch.

Researchers have developed a method of breaking down concrete into its constituent parts. (© Fraunhofer IBP) | Picture in color and printing quality: www.fraunhofer.de/press

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