RESEARCH NEWS

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1 Detecting tumors faster

To diagnose cancer reliably, doctors usually conduct a biopsy including tissue analysis – which is a time-consuming process. A microscopic image sensor, fitted in an endoscope, is being developed for in vivo cancer diagnosis, to speed up the detection of tumors.

2 Crash helmet with a useful smell

Cycle helmets are available in a wide range of types, including foldable models, models fitted with a flashing rear light or featuring an iPhone display. In future, they will start to smell distinctively if they need to be replaced. A new process causes odoriferous oils to exude from plastic materials if they are cracked.

3 Ultra-precise optical systems for space

Metal mirrors made with extremely high precision and exactly positioned are the key elements of modern telescopes. A new production technique enables complex optical surfaces to be manufactured with excellent trueness of shape and hitherto unattained positional accuracy. The mirrors have been built for an infrared sounder telescope.

4 Brilliant counterfeit protection

Counterfeit products create losses in the billions each year. Beside the economic damages, all too often additional risks arise from the poor materials and shoddy workmanship of »knock-off artists«. Yet with the aid of fluorescing dyes, materials can be individually tagged and identified with certainty.

5 Bone replacement from laser melting

In a medical emergency, a puncture of the cranium is commonly treated with an implant. While replacements made of titanium merely plug holes, a new kind of degradable implant stimulates the body to regenerate itself: It is custom-fit and disappears to the same extent that the bone regrows.

6 World of lights in the microcosmos

Light-emitting diodes are gaining ground: They are now being used as background lighting for displays. But the manufacturing of complex LED optics is still complex and expensive. A new technology is revolutionizing production: Large-scale LED components can now be manufactured cost-effectively.

The Fraunhofer-Gesellschaft is the leading organization for applied research in Europe. Its research activities are conducted by 59 Fraunhofer Institutes at over 40 different locations throughout Germany. The Fraunhofer-Gesellschaft employs a staff of around 17,150, who work with an annual research budget totaling 1.6 billion euros. Roughly two thirds of this sum is generated through contract research on behalf of industry and publicly funded research projects. Branches in the USA and Asia serve to promote international cooperation.

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Detecting tumors faster

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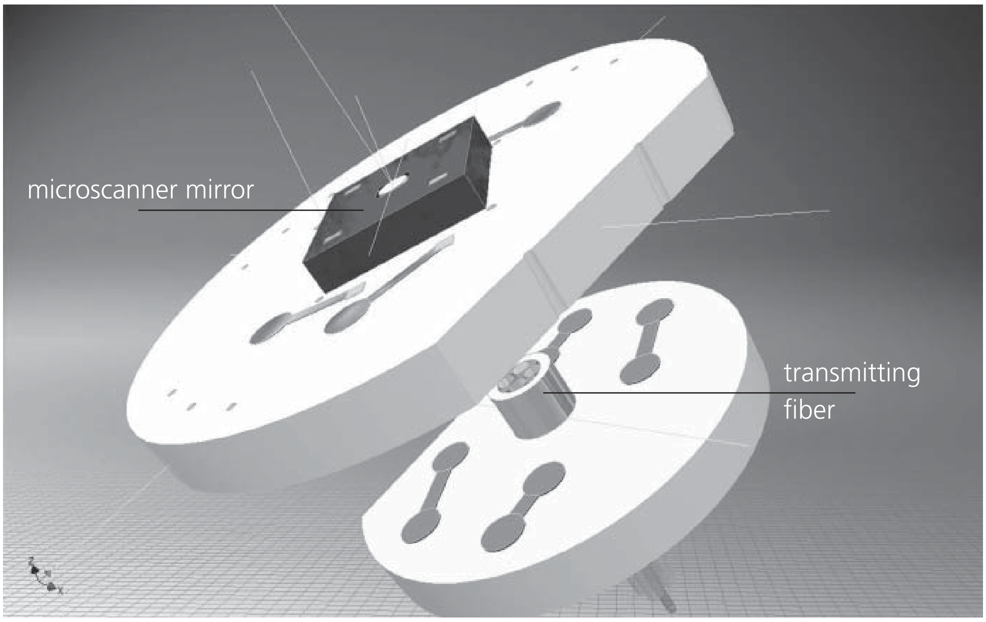
Early detection is the key to the successful treatment of cancer. But not every lump turns out to be a malignant tumor. To find out whether cancerous cells are present, doctors usually conduct a biopsy and examine the removed tissue under the microscope. This process is not only very stressful for the patient but also highly time consuming. Research scientists at the Fraunhofer Institute for Photonic Microsystems IPMS in Dresden are aiming to considerably speed up cancer diagnosis. They have developed a microscope head with a diameter of just eight millimeters which can optically resolve and magnify tissue cells measuring just 10 to 20 micrometers. Fitted in the tip of an endoscope it will be used for in vivo cancer diagnosis, inserted in the body as in a minimally invasive surgical operation. The scientists envision that the MEMS (micro-electro-mechanical system) microscope head will eliminate the need for biopsies. Diagnosis in real time would enable doctors to decide on the necessary course of treatment more quickly.

»Microscopic image recorders that can be used on endoscopes have not been available up to now. We have developed the first laser-based sensor for this purpose,« says Dr. Michael Scholles, business unit manager at the IPMS. »In classic endoscopy using macroscopic imaging, the job can be done by CCD or CMOS image sensors, as used in digital cameras and cellphones. For endomicroscopy, however, MEMS-based image sensors are highly advantageous because they can magnify even the smallest object fields, such as cells, without the need for a large lens. We have combined the sensor with a microscanner mirror to achieve the required resolution of 10 micrometers and can therefore massively magnify the tiniest structures.«

But how does the system function? The laser itself is located in the operating theater. The laser light is conducted via a transmitting fiber to the microscanner mirror fitted in the tip of the endoscope. This deflects the laser beam and illuminates the suspicious tissue specifically. A glass-fiber bundle in the tip of the endoscope transmits the reflected light to the external sensor, which thus receives a signal containing the image information. A detector precisely measures the position of the scanner mirror, indicating which area of the scene is being illuminated at the specific point in time. A two-dimensional image can thus be completely reconstructed by combining the position and image sensor signals.

»An important aspect of the development was to produce a suitable microassembly for the endoscope head. Here we faced the challenge of making the complete system suitable for installation in the endoscope, and we managed to do it. In future our microscope head will be produced in large quantities in an automated process for subsequent installation in endoscopes,« explains Scholles. The expert envisages a wide range of applications for the system: »It could be used not only in medical and biological microscopy but also in technical endoscopy, for instance to examine cavities in buildings or to inspect the insides of engines and turbines.« The microscope head has already been produced as a demonstrator and can be seen at the Optatec trade show in Frankfurt from June 15 to 18 (Hall 3, Stand D50).



The fiber transmits the laser light to the microscanner mirror. Both are fitted in the tip of the endoscope. (© Fraunhofer IPMS)

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Crash helmet with a useful smell

Cycling crash helmets have just one purpose: to protect the cyclist's head. But only completely damage-free helmets do the job properly. It is therefore recommendable to buy a new one every now and again, but nobody wants to throw away a perfectly good helmet. It would be better to know for certain that this is really necessary. A new process developed by research scientists at the Fraunhofer Institute for Mechanics of Materials IWM in Freiburg in cooperation with the Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT in Oberhausen makes this possible. The polymer materials or plastics produced by the process start to smell if they develop small cracks. Large cracks really cause a stink. The smell comes from odoriferous oils enclosed in microcapsules. »Cyclists often replace their helmets unnecessarily after dropping them on the ground, because they cannot tell whether they are damaged or not. The capsules eliminate this problem. If cracks form, smelly substances are released,« explains Dr.-Ing. Christof Koplin, research scientist at the IWM. The capsules are added to a polypropylene mass which is injection-molded to form the final component. In the case of the bicycle helmet, the microcapsules are inserted in a thick foil made of polypropylene, which is fastened to the head gear.

A layer of melamine formaldehyde resin encloses the capsules so that they are completely airtight and mechanically sealed. It also protects the tiny pods, which are subjected to temperatures of 200 to 300 degrees during injection molding as well as static pressures of up to 100 bar. »Melamine formaldehyde resin proved to be the most suitable encapsulation material in the comparison we conducted of the material systems,« explains Koplin. »Inside the capsule there is a porous, hardly deformable silicon oxide core which absorbs the odoriferous substance. This core produced the best results,« he adds.

To determine the loads at which the miniscule capsules measuring just 1 to 50 micrometers break open, the scientists test them at the IWM with a Vickers indenter. The engineers calculate the number of capsules required by means of numerical computer simulation. The finished component is then subjected to bending and drawing tests. The tests are only deemed to be successfully completed if the capsules are found to open and exude the odoriferous substances just before the component fails. Koplin: »Our method of detection by smell offers several advantages. It not only indicates when safety-critical polymer components need to be replaced. The exuding smells also enable damage outside the safety range to be detected.«

The process is therefore suitable for all products which are difficult to test for defects, such as cycle, motorbike and construction helmets. But it can also be used to check pressure hoses, e.g. in washing machines, which are difficult to access. Smell sensors could also monitor plastic water and gas supply pipes to detect any cracks, because the odoriferous substances emitted are noticeable over long distances. »Smell detection is already in use for coated metal components. We are applying the process for the first time to polymer materials. The cycle helmet is being used as a demonstrator. Work on the capsules has finished and we are now completing characterizing tests on individual configurations,« states Koplin.

The damaged helmet releases odoriferous substances. Bottom right: the opened microcapsule. (© Fraunhofer IWM)

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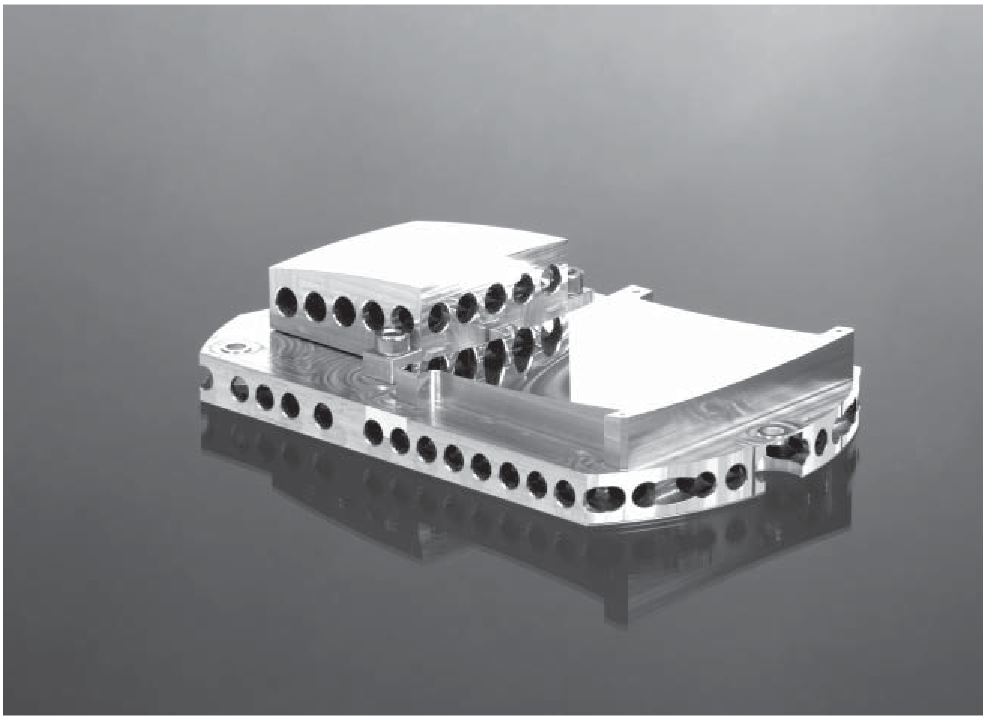
Ultra-precise optical systems for space

For space research as well as climate observation and weather forecasting satellites need increasingly powerful optical measurement and recording devices. They often consist of several aspherically shaped mirror elements which through their precise interplay provide the desired reflection of the incident light. »All the mirrors must be produced and characterized with extreme precision, that is to an accuracy of less than one micrometer. They also have to be exactly positioned in relation to each other,« explains Sebastian Scheiding from the Fraunhofer Institute for Applied Optics and Precision Engineering IOF in Jena. Up to now this positioning has been very time consuming as it takes place step by step. First the individual mirrors are fitted in the telescope one after the other, then the imaging quality is measured. If inaccuracies or errors are found, they are corrected by positional adjustments to the mirrors. Then further measurements and adjustments are made until all components are optimally arranged.

»We wanted to simplify this complicated and time-consuming adjustment process,« says Scheiding. In the research project initiated by the German Aerospace Center (DLR) the scientist has therefore developed an innovative production technique which takes into account the later alignment of the components right from the outset. For this purpose, the individual mirror surfaces are positioned in relation to each other as precisely during processing as they will be later in the telescope. This reduces to a minimum the errors and corrections made when the mirrors are being fitted. The assembly process is simple and reproducible.

»The trick is that we mount all the mirrors for a module in the same machine at the same time and assign them to a common system of coordinates. To this end, each mirror blank is provided with defined, ultra-precise measurement marks and reference surfaces,« explains Scheiding. These fixed marks embody the system of coordinates for diamond turning of the mirror shapes. At the same time, however, they fix the position of each mirror in relation to the adjacent mirrors. Finally they also serve as reference points for subsequent measurement processes to check the quality of the optical system.

The IOF demonstrates the degree of precision that can be achieved by such reference structures on the example of a mirror arrangement for an infrared sounder telescope (IRS-TEL). It incorporates two mirror modules, each of which has two juxtaposed aluminum mirror surfaces. The shape of the metal mirror deviates only 126 nanometers from the ideal aspherical shape and the position of two mirrors in relation to each other is ten times more precise than for comparable conventionally produced mirror assemblies. »As a result we can make optical systems of this type to a far greater degree of accuracy, but at the same time we're cheaper because the time-consuming adjustment process during final assembly is no longer required,« says Scheiding. The IOF's mirror module is on display at the OPTATEC international optical trade show from June 15 to 18 in Frankfurt (Hall 3, Stand D50).



The M2/M3 assembly with two exactly aligned aspherical mirrors from the IRS-Tel reflecting telescope was produced with extremely high precision by using additional reference marks. (© Fraunhofer IOF)

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Brilliant counterfeit protection

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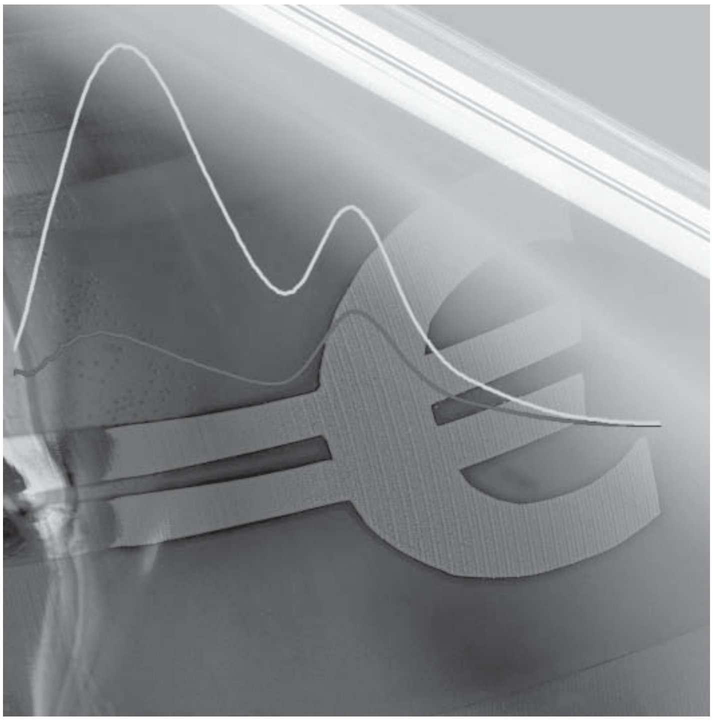
For quite some time now, product piracy has been affecting more than just consumer goods, like watches and designer clothing. The producer industry also has to combat bogus and qualitatively inferior materials. Specialized security features, like watermarks, bar codes, RFID tags and holograms label the products, and thus safeguard them from falsification, theft and manipulation. So when it comes to security features: the more complicated it is to imitate a brand, the more secure the system. A team of researchers from four Fraunhofer Institutes recently engineered a brand new process that is particularly forgery-proof: »We add various fluorescing dyes to the entire material,« explains Dr. Andreas Holländer of the Fraunhofer Institute for Applied Polymer Research IAP. »With the aid of the fluorescence, we can precisely ascertain specific characteristics, and thereby recognize if we are dealing with the original, and if the quality standards have been met.«

Fluorescence can be found in certain organic dyes: Irradiate them within a certain wave length range, and they emit their own light with a greater wavelength. The type of luminosity – i.e., wavelength and light intensity – depends on the physical and chemical properties of the materials to which the dye was applied. Various dyes react to different properties, such as pH value or viscosity. For example, a certain dye glows in a tightly-interlaced resin more strongly than in one that is not as dense.

To make a product counterfeit-proof, the researchers therefore add multiple dyes to the material. »In this manner, an individualized marker emerges that is exceedingly difficult to imitate,« says Holländer. Thanks to the slight dosing, it is virtually impossible to decode the type and quantity of the dye additives: just a few ppb (parts per billion) of dye concentrates suffice to mark the material. Another advantage: The counterfeit protection definitely cannot be removed. »Using conventional security features, the spot with the labeling can be eliminated from the material, theoretically speaking. But that approach doesn't work with our technology, since the dye permeates the entire material, and itself is a component of the identification label,« says Holländer. Beside counterfeit protection, the process is also suitable for an effective quality assurance, such as with coatings: With the aid of various dyes, manufacturers can monitor the chemical composition, degree of dryness and the thickness of the coat during the production process.

The new technology has already passed the first practice tests: Researchers marked barrier sheets for organic light-emitting diodes (OLEDs) and photovoltaics with dyes a development from the Fraunhofer Polymer Surfaces Alliance POLO. The process is basically ready to be used – however, it still must be adapted to each material. A standard solution would also be contrary to the intention of the inventor: »One reason for the high degree of security of our technology is precisely because there are only material-specific solutions,« reiterates Holländer.



Beside counterfeit protection, the process is also suitable for an effective quality assurance: Here outlines characterize well-bonded and poorly bonded coatings on a function sheet. Such sheets are used to manufacture OLEDs. (© Armin Okulla/Harald Holeczek)

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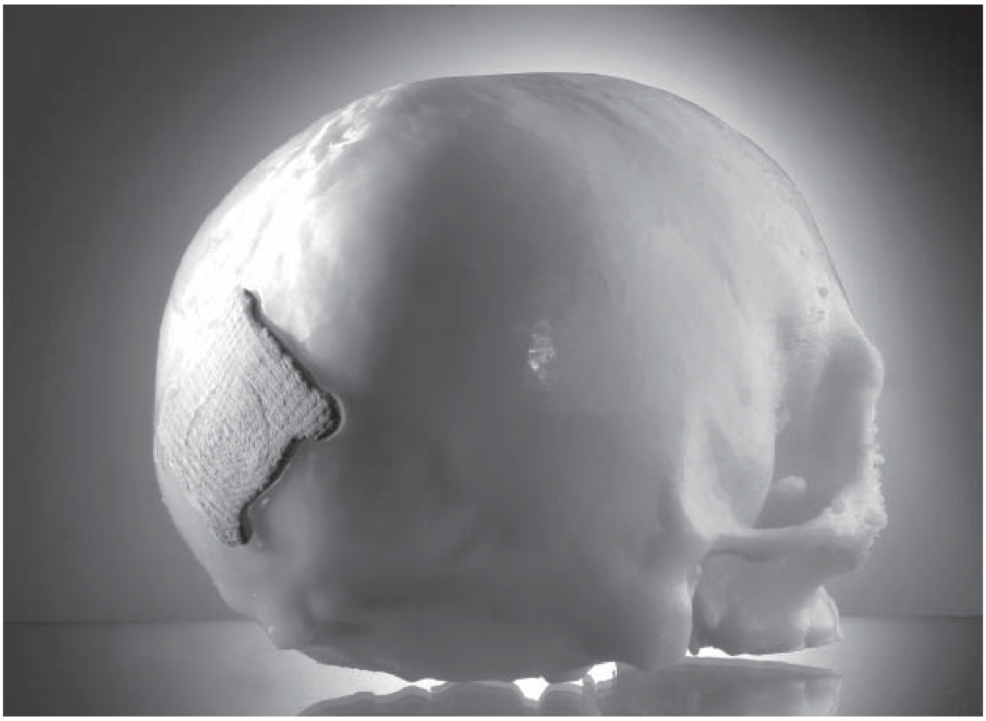
Bone replacement from laser melting

The body can heal minor bone injuries itself - but with major injuries, it needs help. That's when implants frequently come into use. In contrast to long-term solutions based on titanium, degradable implants are intended to replace the missing pieces of bone only until the fissure closes itself up. That may last months or even years, depending on the size of the defect, the age and health status of the patient. A new implant improves the conditions for the healing process. It emerged from the »Resobone« project of the federal ministry for education and research, and is sized-to-fit for each patient. Unlike the conventional bony substitutes to date, it is not made up as a solid mass, but is porous instead. Precise little channels permeate the implant at intervals of just a few hundred micrometers. »Its precision fit and perfect porous structure, combined with the new biomaterial, promise a total bone reconstruction that was hitherto impossible to achieve,« as Dr. Ralf Smeets of the University Medical Center of Aachen summarizes the findings of the first tolerability studies.

The porous canals create a lattice structure which the adjacent bones can grow into. Its basic structure consists of the synthetic polylactide, or PLA for short. The stored granules from tricalcium phosphate (TCP) ensure rigidity and stimulate the bone's natural healing process. As pastes, granulates and semi-finished products, TCP and PLA already have proven to be degradable implants. The body can catabolize both substances as rapidly as the natural bones can regrow. But the material can only be applied in places where it will not be subject to severe stress: Thus, the »Resobone« implants will primarily replace missing facial, maxillary and cranial bones. Currently, they are able to close fissures of up to 25 square centimeters in size. Their unique structure is made possible through a manufacturing process that was developed at the Fraunhofer Institute for Laser Technology ILT in Aachen for the development of industrial prototypes – Selective Laser Melting (SLM): A razor-thin laser beam melts the pulverized material layer-by-layer to structures that may be as delicate as 80 to 100 micrometers.

The patient's computer tomography serves as the template for the precision-fit production of the implants. The work processes – from CT imaging, to construction of the implant, through to its completion – are coordinated in such precise sequences that the replacement for a defective zygomatic bone can be produced in just a few hours, while a five-centimeter large section of cranium can be done overnight. In addition to the obvious benefits, there is a considerable gain in time during surgery: »No custom-fit, degradable implants ever existed before now. During the operation, the surgeon had to cut TCP cubes, or the patient’s own previously removed bone material, to size and insert it into the fissure,« explains Simon Höges, Project Manager at ILT. In addition, the operations are now fewer in number: Physicians no longer take the bone replacement from the patient’s own pelvic bone. Similarly, they can dispense with the countless follow-up operations on children to exchange long-term implants that don‘t grow as the child matures. »We have achieved our project goal: a closed process chain to produce individual bony implants from degradable materials,« explains Höges with satisfaction. Now it is up to the project partners – which also include implant manufacturers – who must turn the results into products.



A degradable implant closes the fissures in the cranial region. It was designed by Karl Leibinger Medizintechnik company. It was manufactured at Fraunhofer ILT. (© Fraunhfoer ILT)

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World of lights in the microcosmos

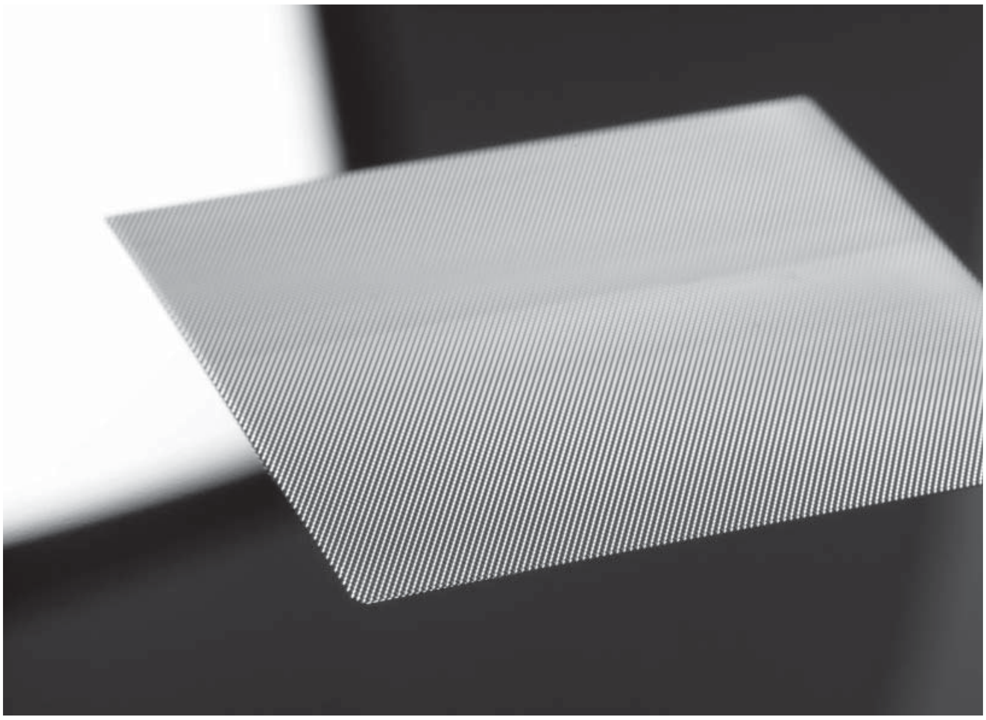
Television screens are becoming increasingly flatter - some have even become almost as thin as a sheet of paper. Their size takes impressive dimensions, much to the delight of home cinema fans. Cellphones and laptops also have ever brighter and more brilliant displays. All of these developments owe their thanks to miniature light-emitting diodes – LEDs – that beam background lighting into a multitude of devices.

However, LED technology does have a disadvantage. It is a point light source. But displays are two-dimensional. So how does one distribute the light from an LED evenly on as large a surface as possible, without massive energy loss? At the Fraunhofer Institute for Production Technology IPT in Aachen, a truly one-of-a-kind machine is currently emerging. They will soon be producing fiber optic film that solves this problem and distributes the light two-dimensionally. What's so unusual and special about this: The films possess superficial structures measuring in the single-digit micrometer range, while the sheets themselves measure at two by one meter in size. This makes them the largest of their kind throughout the EU. In addition, they can be produced cost-effectively and with energy-efficiency in mass reproduction.

To do so, the researchers of IPT developed a process chain with which they can populate large-scale sheets with the necessary microstructures. »It's an ultraprecise process,« says Dr. Christian Wenzel, senior engineer at IPT. Using pinpoint accuracy, the machine must apply the smallest structures – just a few micrometers in size – onto the surface of the film in a periodic sequence. »In order to produce the stamp, we use special diamond tools,« explains Wenzel. The stamp consists of a gossamer-thin nickel sheet, and itself is also infinitesimal: Its surface equals at most two by two millimeters. Like a dot matrix printer, it must then process a sheet measuring two by one meter in size, guided by the ultraprecision machine. »Within a few days, we completely structured the entire surface. With the previous approach, the process would have taken weeks, or even months,« says Wenzel. The preliminary product is the master: a transparent and optically conductive plastic panel.

In order to determine if the microstructured master possesses the desired characteristics, it must first be tested based on a few parameters. »The machine can accomplish this task as well,« says Wenzel. If the approximately 80 percent of the surface is completely structured, the machine tests the properties of the sheet. If these properties are not consistent with the optical design settings, then the machine can implement the necessary corrections during the imprint process. »Well, we are optimizing the component while it's still in the machine,« as Wenzel explains the advantages. Once the plastic surface has the desired light control capabilities, then the engineers immerse the master into a nickel bath and galvanize it. The nickel shim created in this manner can then go into mass replication.

»With our ultraprecise machine, we are capable of producing an entire array of systems with background lighting,« says Wenzel. No matter if it's for displays, architectural lighting or a car's interior lighting: IPT researchers can implement almost any optical design, thanks to this machine, and adapt the machine technology – reliably, and above all, efficiently. In other words: ready for mass production.



The superficial structures of this sheet are only a few micrometers in size. (© Fraunhofer IPT)

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