Fraunhofer

RESEARCH NEWS

10 | 2015 ||

1 Lighting the way to your car

On the new BMW 7 Series, a lighting system featuring a striped pattern of ground illumination makes it easier to enter the vehicle in the dark. Fraunhofer researchers have developed special microoptic lenses for this application to channel light from the vehicle underbody directly onto the ground, illuminating the path to the car.

2 Proteins from rice – raw materials instead of waste

Proteins remain after starch is extracted from rice. Until now, this valuable raw material was disposed of by rice starch producers at great expense. A new process is being developed to split proteins into smaller pieces, or peptides, and then clean them. The peptides can be put to good use in products such as cosmetics or nutritional supplements.

3 Brilliant colors from environmentally friendly crystals

Quantum dots have made it possible to substantially increase color quality in LCD displays. However, these cadmium-based nanocrystals have proven to be harmful to the environment. Fraunhofer researchers are working together with an industry partner to develop a promising alternative: quantum dots based on indium phosphide.

4 Positioning systems improve airport logistics

An airport apron bustles with traffic. The tow tractors, tankers and buses moving busily around an aircraft run the risk of colliding. An enhanced positioning system will increase safety and the efficiency of logistical operations in the future – available airport capacities will be utilized better.

5 Rapid analysis of kidney stones

Kidney stones rank among the most common illnesses. Their recurrence might be prevented with the right postoperative care. However, for this to be effective, composition of the stones should be known. Fraunhofer researchers are developing a system for rapid analysis of urinary stones immediately after the surgical procedure.

6 Low-cost wafers for solar cells

Silicon wafers are the heart of solar cells. However, manufacturing them is not cheap. Over 50 percent of the pure silicon used is machined into dust. A new manufacturing technique developed by Fraunhofer researchers puts an end to these material losses, with raw material savings of 50 percent along with an 80 percent reduction in energy costs.

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.

Editorial Notes:
RESEARCH NEWS l Frequency: monthly l ISSN 09 48 - 83 83 | Published by Fraunhofer-Gesellschaft l Communications l Hansastraße 27 l 80686 München l Phone +49 89 1205-1333 l presse@zv.fraunhofer.de | Editorial Staff: Beate Koch, Britta Widmann, Tobias Steinhäußer, Tina Möbius, Janine van Ackeren 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.

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Lighting the way to your car

RESEARCH NEWS
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You've just enjoyed dinner at your favorite restaurant and now it's dark outside. Unfortunately, the restaurant parking lot is rather poorly lit, but the driver knows what to do. With just a press of the key fob, a striped carpet of light appears on the ground illuminating the path to the car.

This design element available on the new BMW 7-series is based on special microoptics developed by the Fraunhofer Institute for Applied Optics and Precision Engineering IOF in Jena. "Thanks to these specially designed microoptics it's possible to project light beams from the underbody to the ground in a striped pattern covering around four square meters at the vehicle doors on both sides," says Dr. Andreas Bräuer, Microoptic Systems department head at the IOF. These guide lights are not a completely new feature, and other premium carmakers are also working on similar systems for their vehicles. To date, though, these lighting systems have been installed in either the exterior mirror or the door. This is problematic: When integrated into the mirrors, the light moves away from the path it is supposed to illuminate when the door is opened; placed at the bottom of the door, the light cannot reach the ground below until the door is opened.

The BMW Welcome Light Carpet is different. With this system, the lighting module is installed on the body sill to the vehicle underbody under the driver's door. How then is it possible for the light to travel "around the corner" to the path leading to the door? "Our microoptics feature microlenses that aim the light directly at the desired surface," explains the IOF's Dr. Peter Schreiber, who oversees the project. Initially, the IOF scientists' goal was to create tiny yet powerful digital projectors such as those used in smartphones. In physical terms this is a contradiction, as smaller projectors produce less light. However, the IOF experts have found a solution to this problem. They make the projectors extremely small, but they put many of them together in a honeycomb array. "We can alter the intensity of the light by altering the number of microprojectors used," says Bräuer. "Regardless of whether we use 150 projectors, as with the BMW Welcome Light Carpet, or we use 3,000 of them, the thickness of the array still remains within a range that is measurable in millimeters."

Projection lenses can be arranged individually

One positive side effect of this type of array lighting proved quite significant during the development of the Welcome Light Carpet. The projection lenses that catch the light and reflect it onto another surface can be individually positioned relative to the light source. As a result, the images reflected by the individual lenses in different locations can be made to precisely overlap one another. "This means we can project a high-quality and high-intensity image even if the angles of illumination are extremely low. In its first consumer application as the BMW Welcome Light Carpet, this technology gives the BMW 7 Series a new nighttime look," says designer Marcel Sieler of BMW, who is also a member of the IOF team. For the application in the car, the IOF scientists constructed a 10 x 10 mm ² microoptic assembly that is fitted with a glass cover. To protect the sensitive device against stones thrown up while driving, the opening was positioned on the underbody facing away from the direction of travel. Meanwhile, minor smudges of dirt on the glass cover are no problem for the specialized optics because the numerous individual projectors represent a multi-channel lighting design: Dirt may reduce the brightness under certain circumstances, but the light will never be completely blotted out.

The BMW Welcome Light Carpet is now standard equipment on the new BMW 7 Series. "This marks the first time our technology has been applied in a volume market," Bräuer adds happily. Yet the development team also has its eyes on new application areas. "There is an extremely wide range of possible uses for this type of array lighting, extending from safety technologies and medical applications to mechanical engineering and traditional signal lighting," he says.

Microlenses project light onto the entry area of the new BMW 7 Series. (© BMW) | Picture in color and printing quality: www.fraunhofer.de/press

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Proteins from rice – raw materials instead of waste

RESEARCH NEWS
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Rice contains many valuable nutrients and serves as a staple food for large parts of the world's population. The rice grain is made up primarily of rice starch. A number of producers extract and resell this starch, for instance as gluten-free or allergen-free baby food. The proteins left over during this process are disposed of by producers in a number of ways, and also at high cost. However, due to their physiological activity, these proteins can be very useful in items such as nutritional supplements or cosmetics. They are an all-natural product that is easily absorbed by the human body.

As a part of the EU project BIORICE, researchers at the Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT in Oberhausen are currently working together with other European partners to develop a process that can harness this valuable raw material. "We have taken a by-product that generated additional expenses and converted it into a valuable commodity that can be used in foodstuffs and cosmetics," says Fraunhofer UMSICHT scientist Dr. Jürgen Grän-Heedfeld. "For this material, that is something new and unique."

Peptides sorted by size

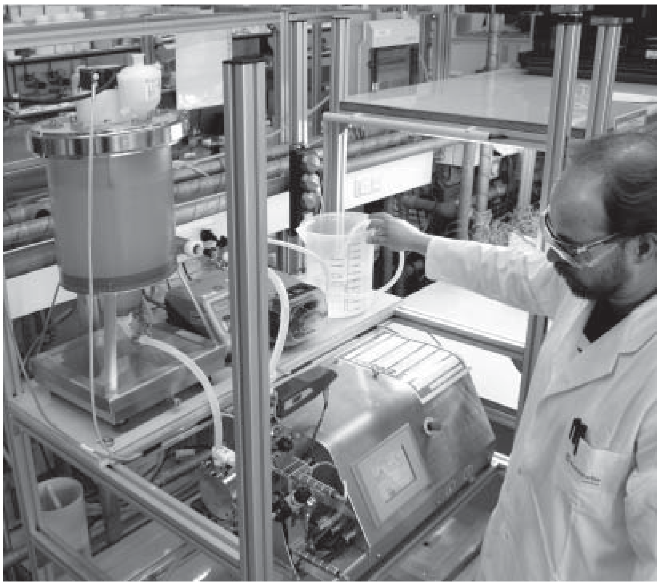
But how are the proteins processed? First, the Italian project partners at the University of Bologna split the proteins into fragments called peptides. "We separate these peptides according to size, which is to say we sort them," says Grän-Heedfeld. To do this, the researchers use various membranes that work like filters. First they filter the peptides, which are suspended in an aqueous solution, through a membrane with a pore diameter of 0.2 micrometers. The larger undigested proteins, which can be seen with the naked eye, cannot pass through the membrane. The solution that has passed through is clear, as the peptides contained within are too small to be seen by the human eye. Next, the scientists filter this solution through three additional membranes with different pore diameters, which results in peptides of four different sizes. The advantage of this method is that it employs only physical separation methods without the use of any chemicals, so the end product is completely pure. By now, the scientists have already successfully increased the scale of the process. Instead of the original 15 to 200 milliliters, they are now working with solution volumes of up to 20 liters.

A gentle drying process

In a subsequent step, the scientists dry out the four separated solutions that remain after filtration. To do so, they perform an established and non-damaging process known as freeze-drying, which is also used for the berries found in breakfast cereals, in addition to spray drying. During freeze-drying, a vacuum extracts moisture from the product and the water vapor is frozen onto a condenser. This process is extremely gentle, but also very energy-intensive. The spray-drying process is somewhat rougher on the proteins, but it is also faster. Here, a nozzle sprays the solution into a current of hot air that dries the protein particles in just fractions of a second. What is then left over is the pure peptide, which looks something like powdered milk. "In this way, we can easily manufacture peptides in quantities of 100 to 200 grams in the laboratory," explains Grän-Heedfeld. The main challenge entails preventing thermal damage and keeping the peptides stable. These are natural products that can easily become discolored or even moldy. "The manufacturing process involves many parameters, and setting them properly requires a great deal of experience and expertise," says Grän-Heedfeld.

The peptides produced using this process are a completely new product, since nothing else currently on the market is derived from the same raw material. Yet to the human body they are already quite familiar. After all, when we eat rice, our stomach breaks it down into even smaller amino acids, which is to say into the building blocks of peptides and proteins.

At the end of the peptide production chain is an SME enterprise headquartered in Switzerland and Italy which will bring them to market. However, before reaching supermarket shelves as ingredients in creams and nutritional supplements, the peptides must still undergo a number of tests and analyses, primarily with regard to their tolerability and effectiveness.



Peptides harvested from rice proteins are sorted by size using a special filtration technique. (© Fraunhofer UMSICHT) | Picture in color and printing quality: www.fraunhofer.de/press

Brilliant colors from environmentally friendly crystals

RESEARCH NEWS
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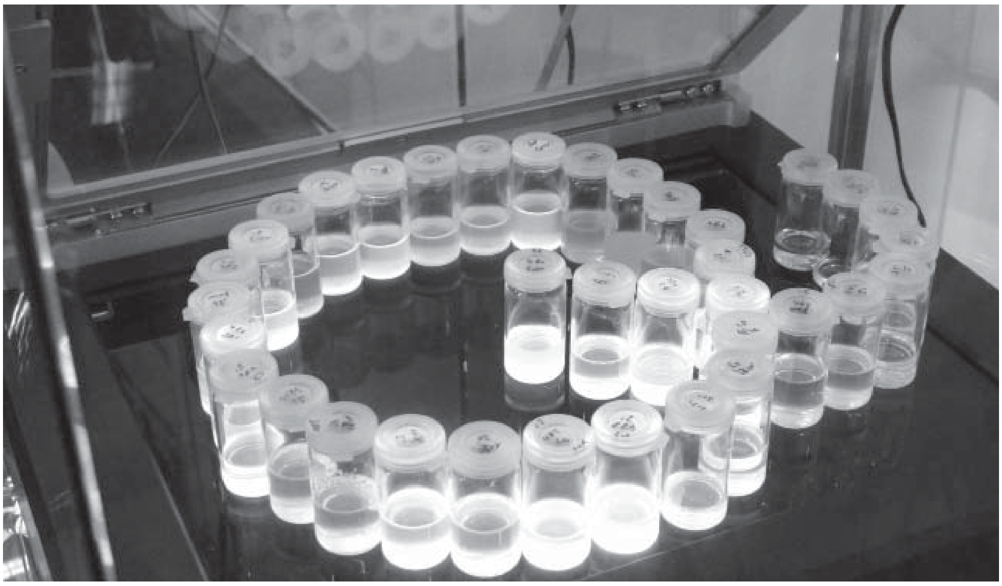
The landscape is breathtaking. Because it is so real, you forget for a moment that the eagle circling the sky is not outside your window, but is instead on your television. Such deceptively realistic images are not only a result of the high resolution displays available on modern devices; the colors play a role as well, and they are becoming ever brighter and richer. This is possible thanks to tiny crystals known as quantum dots (QDs), which have a thickness of merely a few atoms. These nanoparticles located in the backlight units of QD LCD displays offer a cornucopia of colors, but also they possess another extraordinary characteristic. "One big advantage of quantum dots is that their optical properties can be selectively modified by changing their size," explains Dr. Armin Wedel of the Fraunhofer Institute for Applied Polymer Research IAP in Potsdam, Germany. "This means you no longer have to manufacture three separate materials for the colors red, green and blue; now it is possible to do the job with just one." This saves both time and money.

Over the last several years, Fraunhofer IAP researchers in Potsdam have been developing quantum dots for customers in a wide range of industry sectors. They manufacture the nanoparticles using chemical synthesis and customize them for each application. This initially results in very small particles that radiate blue light. At sizes above approximately 2 nanometers, the color changes to green. The largest of the quantum particles, at 7 nanometers in size, emit within the red spectral range. Currently, Wedel and his team are developing quantum dots for display backlighting on behalf of Dutch company NDF Special Light Products B.V. These quantum dots will improve the color rendering and color realism of the displays. Here, the crystals are manufactured for the different emission colors and embedded in plastics. These plastics are subsequently processed into films and built into the display as a conversion film.

Alternative materials based on indium phosphide

With this task, researchers are facing a new challenge. The EU Commission is currently considering a ban on cadmium in consumer goods by 2017, because of its damaging effect on the environment. However, it is also considered to be the ideal material for manufacturing the crystals – cadmium-based quantum dots can achieve a narrowband spectrum sharpness of just 20 to 25 nanometers. Display manufacturers around the world are now looking for suitable replacement materials with similar characteristics. Against this backdrop, Fraunhofer IAP looks to be on a promising path. "We are testing quantum dots based on indium phosphide together with NDF Special Light Products," says Wedel. His team has already managed to achieve a spectral sharpness of 40 nanometers. At first glance, that does not seem too far away from the quality achievable with cadmium-based quantum dots, but the differences in color fidelity are still present. "We see this as a good first milestone, but we are still striving for further improvement," says Wedel. This effort is set to pay off, as television manufacturers are not the only ones who covet these little color wonders. There is also great market potential for special applications such as medical or aeronautical equipment displays. Furthermore, quantum dots can also increase the efficiency of solar cells, or can be employed in bioanalytics. For such special cases, the optical characteristics of the quantum dots must be precisely configured to the specific application requirements. “We’re in a good position thanks to our extensive experience in manufacturing quantum dots to meet specific customer requirements,” says Wedel.



Quantum dots make it possible to display any color in full brilliance. (© Fraunhofer IAP) | Picture in color and printing quality: www.fraunhofer.de/press

Positioning systems improve airport logistics

RESEARCH NEWS
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Dense fog is hanging over an airport apron. Even when tow tractors, pushback tractors and tankers are moving at merely a snail's pace, collisions can always occur, be they with other vehicles or with aircraft. Tanking and loading of luggage, air cargo, and catering takes significantly longer in fog or driving rain than when visibility is clear. Passengers end up sitting at departure gates longer than planned, and the schedule for cargo containers is jeopardized, too. Poor weather conditions will impede work on the apron far less in the future. Researchers at the Fraunhofer Institute for Factory Operation and Automation IFF in Magdeburg are establishing the basis for this in the EU project e-Airport together with various European partners. This project is receiving funding from the European GNSS Agency under the European Union's Horizon 2020 research and innovation programme.

"We are developing a positioning system that will increase safety on the apron," explains Olaf Poenicke, research manager at the Fraunhofer IFF. "It will additionally make it possible to utilize airport capacities more efficiently because the system allows logistical operations to run in a significantly more structured way than before." One important aspect: The steady increase of air traffic is compelling airports either to build new runways and terminals or to utilize the existing infrastructure's capacities more efficiently.

The European Galileo satellite system is the basis of the novel positioning system in the e-Airport project. The principle is similar to that of an automotive navigation system: Tow tractors, pushback tractors and other vehicles have onboard receivers for global navigation satellite systems, GNSS for short, which are powered by the vehicle's power system. They receive signals from the Galileo satellites and other systems such as GPS and use them to establish their exact location. Positioning data are sent by WLAN or cellular radio, for instance, to the control center where all data converge. The control system, in turn, sends messages back to the drivers: A display warns when a vehicle is getting too close to another, driving too close to restricted areas or leaving a specified route. "We at the Fraunhofer IFF are contributing our expertise in air cargo to this control center, modeling the processes, and specifying the job orders received by a tow tractor driver," explains Poenicke. The process models help define ideal target processes. They are compared in the control center with actual data sent from the apron by sensors. Discrepancies can thus be identified, and instructions derived from them can be sent to tow tractor drivers.

Although positioning systems that determine vehicle locations exist, they are based on GPS. This entails problems, especially in the vicinity of buildings. Shadowing occurs; positioning data are imprecise or break off completely. This doesn't happen in e-Airport: Additional signals from the Galileo satellites and other correction signals from the European EGNOS D-GPS system increase accuracy and reliability substantially.

Getting containers and pallets to their destinations faster

Up to now, tow tractor drivers have usually received printed work assignments. Where do they have to hitch which dollies, i.e. trailers loaded with air cargo pallets or containers? Where should they deliver them? Errors occur time and again. Dollies are parked on the airport premises and forgotten, for instance, and have to be hunted laboriously later. “Our system eliminates such errors. It knows both the desired and actual status and gives the driver pertinent work instructions,” says Poenicke.

The researchers are additionally developing special wireless sensors, which are attached to dollies. They use an energy-saving wireless protocol to send their data, e.g. a trailer’s identification number and load, to a receiver unit in the tow tractor. The unit automatically analyzes which dollies are hitched and relays the dolly data together with the tow tractor’s positioning data to the control center. The latest status data keeps the e-Airport system always in the know, even about the location of a dolly parked on the apron. In short, the control center has aggregated data not only on vehicles but also on their dollies and the cargo loaded on them.

The researchers will be presenting their e-Airport project at the BVL’s International Supply Chain Conference in Berlin from October 28 to 30 (Booth P/24).

The positioning systems developed in the EU project e-Airport help control processes on airport aprons more efficiently. (© Fraunhofer IFF) | Picture in color and printing quality: www.fraunhofer.de/press

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Rapid analysis of kidney stones

RESEARCH NEWS
10 | 2015 || Topic 5

An increasing number of citizens in western European countries (including Germany) are affected by kidney stone disease. The number of new cases has tripled in the last 10 years. Kidney stones are often no larger than a grain of rice, yet some can grow to a diameter of several centimeters. Sometimes a urinary stone might block the ureter, causing colick pain in the flank. If it cannot be dissolved, the kidney stone is treated using extracorporeal shock-wave therapy or applying minimally invasive endoscopic modalities.

Many patients suffer from disease recurrence and need retreatments. Scientific studies have shown that new stone formation might be reduced by 50 percent if individualized follow-up care and proper metaphylaxis measures are offered to the patient. The recommendations regarding dietary habits or the use of particular medication strategies are based on the knowledge of the stone composition. In collaboration with an industrial partner and the Division of Urotechnology, University Medical Center Freiburg, researchers at the Fraunhofer Institute for Physical Measurement Techniques IPM are developing a novel Raman spectroscopy based diagnostic system for rapid and automated analysis of kidney stones, thus significantly improving patient follow-up care after stone treatment. Fraunhofer researchers in this project are working hand in hand with urologists specialized in modern methods of treating urinary stone disease.

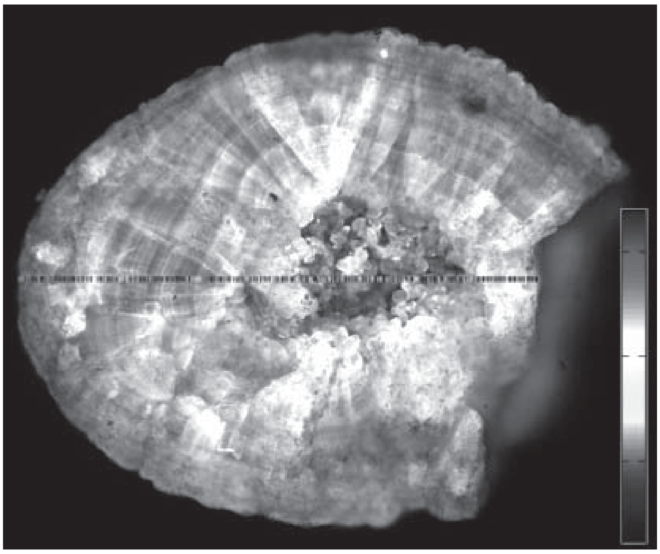
“Only a small number of kidney stone patients receive a comprehensive consultation and follow-up after they have been treated,” says physician and researcher Dr. Arkadiusz Miernik at Fraunhofer IPM. This may be because conventional stone analysis technologies such as infrared spectroscopy are costly and time-consuming, including preperation of stone samples. Analysis can also only be performed in a dedicated laboratory facility. Since only a few centers offer this type of analysis, it can take up to three weeks to receive results. “The patient in most cases has already been discharged and will not be seeing the doctor again. We advise stone patients to drink plenty of fluids, increase physical activities and lose weight if necessary. Unfortunately this is only a general recommendation. From the clinical point of view we need individualized approaches and these must include results of a compositional analysis of the stone. This allows us to evaluate the individual risk of disease recurrence and detect potential metabolic abnormalities,” says Miernik.

Preparation of stone samples no longer necessary

Miernik and his team use a technique known as Raman spectroscopy, which allows them to rapidly characterize and conclusively identify specific stone types. This method utilizes a characteristic spectrum in the visible wavelength range of the examined sample called a “chemical fingerprint”. “These samples are illuminated using laser light. About 1 percent of the photons are reflected back in a different wave spectrum highly specific to the sample. We record these signals in a database," explains Miernik. Researchers use computer software to filter out the fluorescent background occuring during Raman spectroscopy using computer software.

This method employs relatively inexpensive optical components, and it also works on wet, unprepared samples. The time taken to prepare specimens is substantially reduced. "The stones previously had to be dried and pulverized prior to analysis. Our system makes this unnecessary. Stone fragments collected during the surgical procedure do not need to be further processed. They can in principle be put directly into the Raman spectrometer for analysis," explains Miernik. Currently there are a few specialized laboratories that can carry out this procedure using large-scale analytical equipment. A compact device suitable for use in a clinical setting and allowing immediate, post interventional automated analysis is not yet available.

A demonstration system, including the hardware and software required for stone analysis developed by the Fraunhofer IPM researchers, already exists as a prototype. This prototype must first be made more compact before it is ready for the market. A unique feature of the system is its spectral database. An information index has been built up of data on the nine pure substances making up 99 percent of urinary stones. The researchers examined nearly 160 kidney stone samples in setting up the software during the first validation phase. Moreover, the results were confirmed after a conventional infrared based analysis in a reference laboratory. "Once the complete system is ready for clinical use, the physician (urologist) will be able to examine stone samples directly after surgical intervention on his own, thus increasing the quality of patients' care substantially." says Miernik.



The new diagnostic system makes intermediate postoperative kidney stone analysis possible. Exemplarily, a stone is being analyzed automatically using Raman spectrosopy. (© Fraunhofer IPM) | Picture in color and printing quality: www.fraunhofer.de/press

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Low-cost wafers for solar cells

RESEARCH NEWS
10 | 2015 || Topic 6

They sparkle in dark blue on the rooftops. In our homes they give us illumination, while providing lamps, refrigerators and other household appliances with electricity. We are talking about solar cells. A key component of these are thin silicon wafers. The manufacture of these wafers is very time and energy consuming, and correspondingly expensive. What's more, around half of the silicon is lost during production of the wafers. The current price for polysilicon is around 15 euros per kilogram, which means that for every kilogram of polysilicon used, about 8 euros' worth of the material ends up as contaminated and therefore unusable silicon.

Fewer material losses and 80 percent less energy

This is not the case with the new process developed by researchers at the Fraunhofer Institute for Solar Energy Systems ISE in Freiburg. "With our method, we can avoid almost all of the losses that occur during the conventional production process," says researcher Dr. Stefan Janz at the ISE. "This means we are reducing material losses by 50 percent while using 80 percent less energy."

In order to understand how the researchers have accomplished this, it is worth taking a look at the conventional manufacturing process for silicon wafers. This process begins with an impure chunk of silicon. The impure silicon is liquefied and purified by adding chlorine. The material thus created is known as chlorosilane. If hydrogen is added to the resulting gas it is then transformed again into high-purity polysilicon. But this is not the crystalline form needed for solar cells. Therefore, the resulting silicon chunks are again broken up, melted at 1450 degrees Celsius, grown using different methods and transferred into silicon ingots weighing 200 to over 1000 kilograms. From these, square-shaped blocks are created and ultimately sawed into small wafers.

Similarly, in the new process researchers first manufacture chlorosilane, heat it to over 1000 degrees Celsius and mix it with hydrogen. "We don't let the silicon just grow randomly, instead we immediately coax it into the desired crystalline form," explains Janz. This is done through chemical vapor deposition. Here, the gaseous silicon flows past the substrate –itself a silicon wafer – and coats its surface. In this way, the wafer grows atomic layer by atomic layer. To make the new wafer easily separable from the substrate, researchers will introduce a mechanical breakpoint beforehand in the form of porous silicon. These substrates can be reused several dozen times. Not only do the substrates serve as a "backing plate", they also provide the necessary crystal information. This is because for solar cells, a silicon crystal is needed in which the atoms are arranged in a regular array, much as they are in a diamond. The substrate informs the atoms, so to speak, about how they should arrange themselves from the gaseous silicon. "In this way we get a very good monocrystal, which is the best type of crystal, and the wafers are of the same quality as those produced using conventional methods," says Janz.

Lower-cost solar cells

In short, the wafer grows exactly how the researchers want it to, with no need for cumbersome sawing – a process step that wastes almost half of the high-purity input material.

Another advantage of the new process is that it allows the wafers to be made as thin as desired. With the conventional process, the silicon wafers must be at least 150 to 200 micrometers thick, as otherwise the cutting losses would be too high. But solar cells can make do with far thinner wafers. And the thinner the wafer, the cheaper the solar cell. So the new process saves material in two ways: by avoiding a wasteful wafer manufacturing process and by permitting reduced wafer thicknesses. These gains really add up because cutting the cost of the wafer in half brings down the cost of the entire solar module by 20 percent.

As of June 2015, a spin-off company called NexWafe has assumed responsibility for bringing this new wafer production technique to market. "In the pilot phase of this technology we're working in close cooperation with our colleagues at Fraunhofer ISE," says Dr. Stefan Reber, NexWafe CEO. The completion of the factory and the start of mass production for the lower-cost wafers are slated for late 2017.

Further information: http://www.nexwafe.com/

Wafers are detached during the new process (right), leaving the reusable substrate (left).(© Fraunhofer ISE) | Picture in color and printing quality: www.fraunhofer.de/press