

RESEARCH NEWS

07 | 2012 ||

1 Feel-good glass for windows

Daylight acts on our body clock and stimulates the brain. Fraunhofer researchers have made use of this knowledge and worked with industry partners to develop a coating for panes of glass that lets through more light. Above all, it promotes the passage through the glass of those wavelengths of light that govern our hormonal balance.

2 Non-slip tracheal implants

If a person's windpipe is constricted, an operation in which the surgeon inserts a stent to enlarge the trachea is often the only way to relieve their respiratory distress. But this grid-like implant can slip out of position, closing off the windpipe altogether. Researchers are working on a special surface coating for the stents to keep them in place.

3 Cleaning with sunlight

The sun breaks through the clouds – and surfaces start cleaning themselves! It may sound like magic, but in fact it's all thanks to the addition of titanium dioxide molecules. Activated by UV light, they trigger a reaction which destroys bacteria, algae and fungi, keeping items such as the armrests of garden chairs nice and clean.

4 Keeping electric vehicle batteries cool

Heat can damage the batteries of electric vehicles – even just driving fast on the free-way in summer temperatures can overheat the battery. An innovative new coolant conducts heat away from the battery three times more effectively than water, keeping the battery temperature within an acceptable range even in extreme driving situations.

5 Sailing with nerves of glass

In the world of racing, tiny details can be the difference between victory and defeat. It is no wonder, then, that manufacturers of racing yachts are always on the lookout for new technologies to optimize boats and sails. An ingenious new sensor technology now helps them to extend the boundaries of what is possible.

6 Anti-aging elixir for solar cells

Photovoltaic modules deliver power without risks to the environment and climate. But solar-power is expensive. Therefore, it is imperative that the modules last as long as possible, 25 years or more. Fraunhofer researchers in the USA are now investigating materials to protect solar cells from environmental influences to meet that goal.

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 | Frequency: monthly | ISSN 09 48 - 83 83 | Published by Fraunhofer-Gesellschaft | Press Office | Hansastraße 27 | 80686 München | Phone +49 89 1205-1333 | presse@zv.fraunhofer.de | Editorial Staff: Franz Miller, Janine van Ackeren, Monika Weiner, Britta Widmann | 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.

Feel-good glass for windows

Most people prefer to live in homes that are airy and flooded with light. Nobody likes to spend much time in a dark and dingy room. That's no surprise, since daylight gives us energy and has a major impact on our sense of wellbeing. It is a real mood lifter. But not everyone is lucky enough to live in a generously glazed home, and office spaces – where we spend many hours of each day – are often not exactly bright and breezy. Modern heat-insulating, sun-protection glazing for offices and housing doesn't make things any better, since it isn't optimized to allow the light that governs our hormonal balance to pass through: instead, a distinctly noticeable percentage of incident sunlight in this effective part of the spectrum is reflected away.

Anti-reflective glass that is more transmissive overall to daylight is reserved for certain special applications, such as in glass covers for photovoltaic modules or in glazing for shop windows. The aim with this kind of glass is to avoid nuisance reflections and to achieve maximum light transmission at the peak emission wavelength of sunlight. This is the wavelength at which the human retina is also most sensitive to light. "However, our biorhythms are not affected by the wavelengths that brighten a room the most, but rather by blue light," explains graduate engineer Walther Glaubitt, a researcher at the Fraunhofer Institute for Silicate Research ISC in Würzburg. That is why he and his team have developed glass that is designed to be particularly transmissive to light in the blue part of the spectrum. The secret is a special, long-lasting and barely perceptible inorganic coating that is only 0.1 micrometers thick. "Nobody's ever made glass like this before. It makes you feel as if the window is permanently open," says Glaubitt. One reason the glass gives this impression is that it exhibits maximum transmission at wavelengths between 450 and 500 nanometers – which is exactly where the effects of blue light are at their strongest.

Lack of light gives rise to sleep disorders

Why is it that the blue part of the light spectrum has such an impact on our sense of wellbeing? "There is a nerve connecting the human retina to the hypothalamus, which is the control center for the autonomic nervous system," explains Glaubitt's team colleague Dr. Jörn Probst. Special receptors sit at the end of the nerve connection which are sensitive to blue light, converting it into light-and-dark signals and sending these to the area of the brain that functions as our biological clock. There, one of the things these nerve impulses do is regulate melatonin levels. A lack of light leads to high levels of melatonin, which can result in problems sleeping and concentrating, as well as depression and other psychological impairments. Seasonal affective disorder, also known as winter depression, is one possible outcome of unusually high melatonin levels. "The coating we've developed helps people to feel they can perform better and makes it less likely they will fall ill," says Probst.

Industrial partner Centrosolar Glas GmbH & Co. KG is responsible for applying the coating to the glass while UNIGLAS GmbH & Co. KG, the company that brought the product to market maturity, handles the remaining finishing work as well as sales. It is about to launch a triple-glazing product featuring this innovative glass, for which a patent is pending, under the name UNIGLAS | VITAL® feel-good glass. Fitting triple glazing to a room does not make it seem appreciably darker, but it does affect the light that enters the room in a way that is detrimental to our biorhythms. This is especially true for people who have little opportunity to spend time outdoors and are obliged to spend most of their time in rooms with only small windows. "Thanks to the special ISC coating, this is not the case with our UNIGLAS | VITAL® feel-good glass. Instead, the light quality achieved is very close to that of single glazing," says Thomas Fiedler, the Technical Director of UNIGLAS. Its transmissivity to light is increased across the entire range from 380 to 580 nanometers, which is to say in the portion of the spectrum that is responsible for promoting wellbeing. At 460 nanometers, the light transmissivity of UNIGLAS | VITAL® is 79 percent. Comparable triple glazing only lets through 66 percent of light at this wavelength. Meanwhile, the coating has no impact on the window's heat-insulating properties.

But the ISC researchers haven't quite reached their ultimate goal: "Up to now we've only applied our special coating to the side of the glass facing into the cavity between panes," says Glaubitt. "In future we will also be coating the glazing's exposed surfaces – in other words, the outside and the inside of the window. That will allow us to achieve around 95 percent light transmissivity at 460 nanometers."

Non-slip tracheal implants

When coronary blood vessels are constricted, cardiologists try to prevent a heart attack by widening them with small grid-like implants called stents, which stabilize the veins and arteries, improve the flow of blood and prevent vascular obliteration. A lesser known fact is that stents can be used to treat pathological constriction of the windpipe. This kind of respiratory stenosis, which may be caused by tumors, chronic infections or congenital deformities, can be life-threatening. The metal or plastic stents are designed to enlarge the trachea and prevent it from closing up altogether.

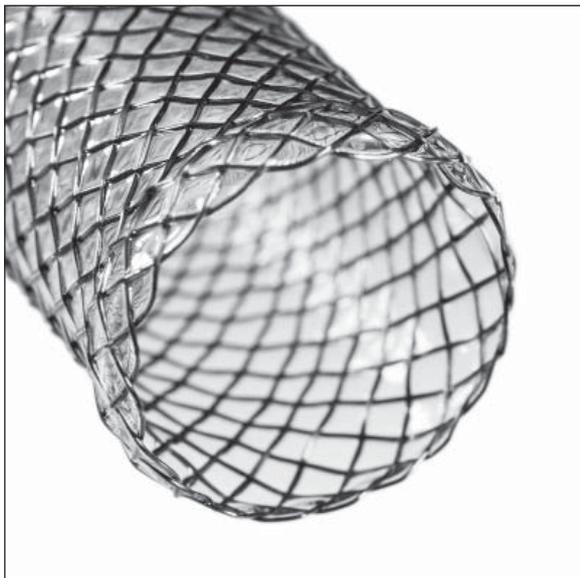
But complications can arise when the implants are inserted. Firstly, there is the danger that the stents will shift, thus partially or completely obstructing the respiratory tract. Secondly, bacteria can colonize the stents and trigger pneumonia. The reason for this is that the stents have no barrier-forming cells of the kind usually present in the respiratory system, whose task is to fend off bacteria and inhaled substances such as particulate. "The windpipe has an important barrier function, with goblet and cilia cells purifying the inhaled air. It is very important that cells like these can adhere to the stents so as to maintain the air-purifying effect of the damaged section of the windpipe and to promote incorporation of the stents in the surrounding tracheal tissue," says Dr. Martina Hampel, a scientist at the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB in Stuttgart. Together with Prof. Dr. Thorsten Walles, head of the department of thoracic surgery at the University Hospital of Würzburg and a visiting scientist at the IGB, Dr. Hampel and her team took part in the "REGiNA" project, the goal of which was to develop surface coatings that enable the stents to be incorporated in the surrounding tissue, thus reducing the risk that they will move. REGiNA, a German acronym for Regenerative Medicine in the Neckar-Alb and Stuttgart Region, is funded by the German Federal Ministry of Education and Research BMBF.

Bioactive coatings lower the risk for patients

The scientists used stents lined with a polyurethane (PU) film, which were produced by Aachen-based Leufen Medical GmbH. In the ensuing tests, a wide variety of different coatings were applied to the PU film: In addition to synthetic polymers composed of organic acids, the researchers also tried out biological proteins such as fibronectin and type-I collagen. The coating was modified again using plasma technology, with vacuum-ionized gas being used to treat the surface. The experts used an untreated PU film for control purposes. "In order to find out which of the surface coatings was the most suitable, we brought both lab-cultivated cell lines and human primary tracheal epithelial cells into contact with the films in cell culture vessels. What we wanted, of course, was for the primary respiratory cells from human tissue to attach themselves to the film," explains Hampel. The researchers achieved their best results with the protein-coated film, on which the primary tracheal epithelial cells grew particularly well and multiplied. "The respiratory cells proved to be more vital on bioactive films rather than on ones

treated with plasma. By contrast, polymer-coated film turned out to be completely useless," says Hampel.

The laboratory tests have since been completed, and animal tests are in preparation. If the good lab results are confirmed in these tests, the next step will be to conduct clinical trials of the modified stents at the Schillerhöhe specialist lung clinic, part of the Robert Bosch Hospital. "We hope that, within just a few years, our well-tolerated, cell-compatible surface coatings will be used for other biomedical prostheses such as pacemaker leads, tooth implants and replacement joints," says Hampel.



A new protein coating is designed not only to enhance incorporation of respiratory stents in the surrounding tracheal tissue, but also to lower the risk of infection for patients. (© Leufen Medical GmbH) | Picture in color and printing quality: www.fraunhofer.de/press

Cleaning with sunlight

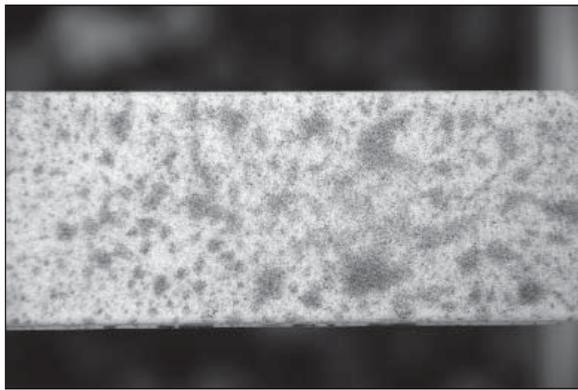
Summer is just around the corner and it's time to dust off the garden tables and chairs. But garden furniture that has been left in the shade too long is often covered with a slimy film of algae, moss, bacteria and fungi which is difficult or even impossible to remove. Scientists are now hoping that they can solve this problem by incorporating titanium dioxide molecules in the plastic used to make the garden chair and adding a little bit of sunlight. When these titanium dioxide molecules are 'activated' by the UV light in the sun's rays, they act as a kind of catalyst, triggering an electrochemical reaction which produces free radicals. These and other active molecules strike a fatal blow to bacteria, fungi and similar organisms, first destroying the cell walls and then penetrating the cytoplasm – the substance that fills the cell – and damaging the bacteria's DNA. As a result, the organic substances are destroyed instead of remaining stuck to the surface.

But just how well do these photocatalytic coatings work? What organic elements do they destroy, and what are they powerless against? These two questions have been the subject of investigation by researchers at the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB in Stuttgart. "For example, we ran some outdoor tests on garden chair armrests with photocatalytic coatings and compared them to ones made from conventional plastic," says Dr. Iris Trick, group manager at the IGB. Dr. Trick and her team sprayed the coated and uncoated armrests with a mixture of various bacteria, mosses, algae and fungi and then left them exposed to the weather for two years. At the end of the test, it was almost impossible to remove the layer of dirt from the normal armrests – yet the armrests made from photocatalytic plastics were still almost completely clean and white, even after spending two years outside. The researchers also tested the effectiveness of their special coatings on armrests and a range of other surfaces in the lab. To do this, they applied up to 30 different kinds of fungal, bacterial and algal cultures to coated and uncoated surfaces and compared how the cultures evolved. In addition, they analyzed the degradation products generated on the self-cleaning surfaces by the electrochemical reaction.

Self-cleaning walls and displays

The opportunities offered by titanium dioxide molecules extend far beyond armrests. For example, researchers from the Fraunhofer Institute for Manufacturing Engineering and Automation IPA in Stuttgart are working on paints for building façades which contain titanium dioxide particles. If the wall gets dirty, the photocatalysis degrades the organic contaminants and the paint stays reasonably clean. The scientists have even developed a self-cleaning coating for glass surfaces: "If you apply a thin coating of titanium dioxide to a glass surface such as a smartphone screen, the skin oils and fingerprints gradually disappear from the display by themselves," says Dr. Michael Vergöhl, head of department at the Fraunhofer Institute for Surface Engineering and Thin

Films IST in Braunschweig and head of the Fraunhofer Photocatalysis Alliance. All that is needed is one hour of sunlight – unlike previous photocatalytic surfaces, which would have required the smartphone to be left in the sun for three days. The next step is to develop new materials that can also be activated by artificial light. The Fraunhofer Photocatalysis Alliance is a group of ten Fraunhofer institutes which have decided to combine their expertise in this field. It covers the full spectrum of photocatalytic surface development and offers considerable know-how from a single source.



The surface coated with titanium dioxide molecules (bottom) looks very different from the non-coated sample (top). (© Fraunhofer IGB) | Picture in color and printing quality: www.fraunhofer.de/press

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Keeping electric vehicle batteries cool

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Batteries provide the “fuel” that drives electric cars – in effect, the vehicles’ lifeblood. If batteries are to have a long service life, overheating must be avoided. A battery’s “comfort zone” lies between 20°C and 35°C. But even a Sunday drive in the midday heat of summer can push a battery’s temperature well beyond that range. The damage caused can be serious: operating a battery at a temperature of 45°C instead of 35°C halves its service life. And batteries are expensive – a new one can cost as much as half the price of the entire vehicle. That is why it is so important to keep them cool. Thus far, conventional cooling systems have not reached their full potential: either the batteries are not cooled at all – which is the case with ones that are simply exchanged for a fully charged battery at the “service station” – or they are air cooled. But air can absorb only very little heat and is also a poor conductor of it. What’s more, air cooling requires big spaces between the battery’s cells to allow sufficient fresh air to circulate between them. Water-cooling systems are still in their infancy. Though their thermal capacity exceeds that of air-cooling systems and they are better at conducting away heat, their downside is the limited supply of water in the system compared with the essentially limitless amount of air that can flow through a battery.

More space under the hood

In future, another option will be available for keeping batteries cool – a coolant by the name of CryoSol^{plus}. It is a dispersion that mixes water and paraffin along with stabilizing tensides and a dash of the anti-freeze agent glycol. The advantage is that CryoSol^{plus} can absorb three times as much heat as water, and functions better as a buffer in extreme situations such as trips on the freeway at the height of summer. This means that the holding tank for the coolant can be much smaller than those of water-cooling systems – saving both weight and space under the hood. In addition, CryoSol^{plus} is good at conducting away heat, moving it very quickly from the battery cells into the coolant. With additional costs of just 50 to 100 euros, the new cooling system is only marginally more expensive than water cooling. The coolant was developed by researchers at the Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT in Oberhausen.

As CryoSol^{plus} absorbs heat, the solid paraffin droplets within it melt, storing the heat in the process. When the solution cools, the droplets revert to their solid form. Scientists call such substances phase change materials or PCMs. “The main problem we had to overcome during development was to make the dispersion stable,” explains Dipl.-Ing. Tobias Kappels, a scientist at UMSICHT. The individual solid droplets of paraffin had to be prevented from agglomerating or – as they are lighter than water – collecting on the surface of the dispersion. They need to be evenly distributed throughout the water. Tensides serve to stabilize the dispersion, depositing themselves on the paraffin droplets and forming a type of protective coating. “To find out which tensides are best suited to

this purpose, we examined the dispersion in three different stress situations: How long can it be stored without deteriorating? How well does it withstand mechanical stresses such as being pumped through pipes? And how stable is it when exposed to thermal stresses, for instance when the paraffin particles freeze and then thaw again?" says Kappels. Other properties of the dispersion that the researchers are optimizing include its heat capacity, its ability to transfer heat and its flow capability. The scientists' next task will be to carry out field tests, trying out the coolant in an experimental vehicle.



CryoSol^{plus} is a dispersion that can absorb three times as much heat as water, and can prevent batteries from overheating. (© Fraunhofer UMSICHT) | Picture in color and printing quality: www.fraunhofer.de/press

Sailing with nerves of glass

The constant hunger to break new records has turned boat building into a high-tech business. The racing yachts that compete at international regattas today are sporting machines designed to reach top speeds. The process of optimizing the boats has been ongoing for decades. However, just a short while ago it looked as if a limit had been reached. On the fifth leg of the Volvo Ocean Race in spring 2012, from New Zealand to Brazil, only one of the six teams reached its destination without technical problems – all the others were forced to either take a break from the race or give up altogether. The regatta became a war of attrition. And yet these yachts are the best in the world.

“These boats are very well constructed,” affirms Ian Walker, skipper of the Abu Dhabi Ocean Racing team. “I just think we put too much strain on them, and since they are so rigid and so light it’s hard not to believe that they ultimately must break.” So how do you build yachts that are faster than the wind and yet stable enough to withstand the harsh conditions on the high seas?

Back on course with sensor technology

A new sensor system from the Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute HHI can help to detect weak points on time and warn yachtsmen when breaking point has been reached. Prof. Wolfgang Schade and his team in the Project Group for Fiber Optical Sensor Systems in the German town of Goslar have developed “nerves of glass” which can measure the forces that act on hulls, masts, and sails. The technology was actually developed for monitoring wind turbines, where rotor blades and cables are exposed to high loads. “With fiber optic sensors, we can detect delaminations and even cracks at any early stage – long before a part breaks or fails,” explains Schade. “All you need is a fiber optic cable, in which dozens of sensors can be fitted.” The centerpiece of the new technology is “fiber Bragg grating”, microscopic structures that are integrated in the glass fiber at defined intervals and which alter the refractive index. Light racing through the glass fiber is reflected by these lattice points. The wavelength of the reflected light depends on the distance between the microscopic structures: every stretching or compression of the glass fiber alters the wavelength. To be able to measure the reflectance spectrum quickly and cheaply, the researchers developed a mini-spectrometer, which consists of a chip that splits light into various frequencies. By analyzing the frequency spectrum, experts can draw conclusions about the forces currently acting on the glass fiber.

The idea to use the measurement technology on sailboats came to Schade during a sailing voyage in the fall of 2010. “Sailing is all about making best use of the wind and being as fast as possible. At the same time, you also have to avoid pushing the equipment beyond breaking point. Fiber optic sensors can help to determine the forces acting on hulls, masts, and sails during the journey in real time.” A few months later, Schade was able to demonstrate that the sensors were up to the task of advancing the

sport of sailing. At the Düsseldorf boat fair he met Jens Nickel, who runs a sail workshop in Stade in northern Germany. In collaboration with the sailcloth manufacturer Dimension-Polyant, a web of glass fibers containing 45 measuring points was fitted to a mainsail and a genoa in Nickel's workshop. Measurements were then conducted on the sails on a test journey. "It turned out that the tension in the head, right at the top of the sail, was greater than assumed," says Nickel. "However, the strain on the clew, the lower aft corner of a sail, and on the entire leech area, the aft edge of a sail, was smaller than had been thought." Nickel's sail workshop used the data right away to optimize their working processes. The sailmaker started reinforcing the areas that were subject to greater stress and using lighter material in the areas that were less stressed.

Schade and his team's next objective is to adapt the measurement technology so it is fit for use in competitive racing. "We have now fitted sail battens with fiber optic sensors, which will help competitors in future to find the optimal trim, i.e. the sail position at which the boat travels the fastest under specific wind and wave conditions," explains Schade. For the first time, the fiber optic sensors and the connected measuring equipment – which is no bigger than a cigarette packet and contains an LED light source, spectrometer, and electronics – are supplying reproducible values. This data tells the crew in which areas there is too much or too little pressure, or how stresses shift to different areas, for example when the sheets are pulled in tighter. The results provided by the sensor technology will be accessible everywhere on board at all times – Schade's team has already developed an app that allows crew members to access real time data from their smart phones. The new measuring system will be launched shortly under the name NextSailSystem.



To measure the forces acting on the sail, researchers have fitted it with a web of glass fibers.
(© Fraunhofer HHI) | Picture in color and printing quality: www.fraunhofer.de/press

Anti-aging elixir for solar cells

Sometimes it's just a couple of cents that decide the success or failure of a technology. As long as solar power, for instance, is still more expensive than energy extracted from fossil fuels, photovoltaics will not be competitive on the broad open market. "Power generation from solar energy continues to be reliant on public subsidies – this is no different in the USA than in Germany," explains Christian Hoepfner, Scientific Director of the Fraunhofer Center for Sustainable Energy Systems CSE in Cambridge, Massachusetts, USA. "If we want renewable energy to penetrate the global market over the long term, then we must ensure it gets cheaper."

There are no silver bullets to reach this target: Efficiency cannot be arbitrarily increased, and it is expensive to produce solar cells and modules. If you want to change something here, you have to solve a puzzle with many variables: Engineering teams around the world are searching for new technologies and production methods to make cells and modules cheaper, more efficient, more durable and reliable.

Silicone – steady and resilient

Silicone is one of the promising materials. It is a highly unusual substance – neither inorganic crystal nor organic polymer – but related to both. While PV modules have been encapsulated with silicones, until now, however, they were not widely used for laminating solar modules. Lamination is a protective coating that surrounds the fragile silicon wafer. Today most manufacturers of photovoltaic cells use ethylene-vinyl acetate, or EVA for short.

In order to determine if silicone could replace the ethylene-vinyl acetate a team of experts worked together: researchers from Fraunhofer and from Dow Corning Corporation, the world's largest manufacturer of silicones used in medical technology, cosmetics, the automotive industry, paper processing and electronics. The scientists coated photovoltaic cells with liquid silicone. "When the silicone hardens, it encases the cells; the electronic components thus have optimal protection," says project Manager Rafal Mickiewicz. The experts at CSE constructed prototypes from the silicone-laminated cells, and tested these photovoltaic modules in a climate chamber at low temperatures and under cyclic loads. Afterwards the module performance was tested with a light flasher. In addition the researchers used electro-luminescence-imaging for the detection of micro cracks. A comparison of the results with those of conventional solar modules proved that silicone-encased photovoltaic modules are more resistant to cyclic loading of the type modules experience in strong winds, in particular at a frosty minus 40 degrees Celsius.

"Dow Corning Corporation collaborated with researchers at the Fraunhofer CSE Photovoltaic Modules Group for two years. This collaboration significantly improved our

understanding of the materials requirements of our solar modules, particularly in regard to sustainability and output,” concludes Andy Goodwin, Global Science & Technology Manager, Dow Corning Solar Solutions.

In the meantime, the tests have been published at the 26th European Photovoltaics Solar Energy Conference in 2011. “The study results demonstrate that silicone lamination is well-suited for certain applications, because the silicone protects the fragile components on the inside well, and moreover, withstands severe temperature fluctuations. With this technology we can, for instance, make modules with thin Si cells more robust,” concludes Mickiewicz.



In this mechanical test stand the researcher examines the quality of silicone-encased solar modules. (© Fraunhofer CSE) | Picture in color and printing quality: www.fraunhofer.de/press