Fraunhofer

RESEARCH NEWS | SPECIAL EDITION | 05-2010

Overview of awards

The Stifterverband Award recognizes scientifically outstanding joint projects in applied research. In addition, at the annual meeting of the Fraunhofer-Gesellschaft, three Joseph von Fraunhofer Prizes and three Hugo Geiger Prizes will be bestowed.

1 A powerful duo: diamond and ceramic

To develop a material with high resistance to wear: that was the objective of a research team. For tools and components specifically subjected to load, their solution delivers an extended product lifespan with better performance characteristics.

2 High efficiency concentrator solar cells and moduls

Solar energy will play a crucial role in the energy mix of tomorrow as solar energy is available in unlimited quantities. With the aid of concentrator solar cells, even more sunlight can be converted into electricity.

3 Synthetic eye prosthesis

Donor corneas are a rarity: In Germany alone, each year roughly 7,000 patients wait for that miniscule piece of tissue. An implant made of plastic may soon offer patients – especially those facing their last resort – with the chance to see again.

4 Sharkskin for airplanes, ships and wind energy plants

To lower the fuel consumption of airplanes and ships, it is necessary to reduce their flow resistance, or drag. An innovative paint system makes this possible. This not only lowers costs, it also reduces CO_2 emissions.

5 Mini-projectors – maximum performance

The number of mini-projector devotees keeps growing. The combination of a new kind of optical structure with high-performance LEDs enables completely new compact and brilliant lighting and projection systems.

6 Materials with potential / Growing through holes

Silicon carbide is an up-and-coming semiconductor material. In a thesis project, the qualities of the crystals and the epitaxial layers underwent precise analysis. Another project combines the advantages of crystalline thin-film solar cells with a back contact structure.

The Fraunhofer-Gesellschaft is the leading organization for applied research in Europe. Working under its auspices are 59 institutes at more than 40 locations throughout Germany. Its approximately 17,000 employees achieve the annual research volume of 1.6 billion euros. Of this, the Fraunhofer-Gesellschaft generates roughly two-thirds of this from industry-based contracts and publicly financed research projects. International collaboration is facilitated by branch offices in Europe, the USA and Asia.

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Overview of awards

Stifterverband Award for Science
In 1920, scientific representatives founded the Stifterverband (Association of Donors) at the recommendation of German academies, universities and scientific institutions. Its reestablishment after World War II is closely tied to the reestablishment of the „Notgemeinschaft der deutschen Wissenschaft“ (German Research Association) on January 11, 1949.

As in the past, the Stifterverband today views itself as intermediary between business and science. Under the aegis of the Stifterverbund, a capital volume of 1.3 billion euros is administered in 350 individual endowments. For the past 8 years, it has bestowed on the Fraunhofer-Gesellschaft a prize endowed with 50,000 euros. This award recognizes the scientific excellence of joint projects in applied research that the Fraunhofer institutes have developed in conjunction with business and/or other research organizations (Article 1) This prize and the „Technology for Humanity“ prize are awarded each year on an alternating basis.

Joseph von Fraunhofer Prize: Research for practical uses
Since 1978, the Fraunhofer-Gesellschaft has awarded prizes each year for the outstanding scientific accomplishments of its employees who solve applications-based problems. Since its inception, more than 200 researchers have won this prize. Each of three 20,000 euro prizes will be awarded this year. The prize winners will also receive a silver lapel pin with the facial profile of the award patron, just like it appears in the logo in articles 2, 3 and 4.

Hugo Geiger Prize: Cultivating future scientific talent
The 50-year anniversary of the Fraunhofer Gesellschaft inspired the government of Bavaria to endow this prize in 1999. It is named after Bavarian State Secretary Hugo Geiger, sponsor of the inaugural meeting of March 26, 1949. This prize is awarded in recognition of outstanding and applications-oriented diploma and doctoral work from all areas of research of the Fraunhofer Gesellschaft. Judgment criteria are: scientific quality, economic relevance, novelty and the interdisciplinary nature of the approaches applied. The projects must bear a direct relationship to a Fraunhofer institute, or have been developed there. This year, the first prize winner (article 5) will receive an award of 5,000 euros; second prize is 3,000 euros and third prize is 2,000 euros (article 6).

A powerful duo: diamond and ceramic

Diamond is a material with outstanding features: It is extraordinarily hard, conducts heat well and is practically inert to chemical substances. Ceramics – particularly high–performance ceramics – are likewise able to demonstrate special qualities: It is robust and withstands extreme temperatures. Scientists from four Fraunhofer institutes, together with partners from industry, succeeded in producing a new composite material and in making it useable for applications. The composite material, „diamond-coated ceramics DiaCer®," combines the best of both materials. Any place where components and tools are subjected to heavy strain – such as in pumps or forming and shaping dies – DiaCer® offers maximum wear-resistance coupled with low values of friction. In recognition of their achievement, the interdisciplinary team is bestowed the Stifterverband Award for Science.

The basis is a silicon-nitride or carbide ceramic, which researchers of the Fraunhofer Institute for Ceramic Technologies and Systems IKTS in Dresden modified for the diamond coating. Their mission was to find out how to craft the ceramics so that the diamond coating adheres firmly and evenly to the base body. That is quintessential to the lifecycle. Colleagues at the Fraunhofer Institute for Materials Mechanics IWM in Freiburg provided important insights on this through simulations with the materials and components; additional insights were gained from the investigations on ceramics processing by colleagues from the Fraunhofer Institute for Production Systems and Construction Engineering IPK in Berlin. „We then worked on the coating, and designed the systems," says project coordinator Dr. Lothar Schäfer of the Fraunhofer Institute for Surface Engineering and Thin Films IST in Braunschweig. Components and tools are initially placed in a vacuum reactor for the hot wire chemical vapor deposition (CVD) technology applied for the coating process. Next, the researchers add methane and hydrogen. In order for the diamond coating to grow, wires are spread at intervals of just a few centimeters across the objects that were going to be coated. The wires are heated until they reach incandescence. This activates the gases; carbon is deposited on the surface in crystalline diamond form. „Using our process, we can apply a diamond layer of up to a half square meter in size," says Schäfer. „There's nothing else like it in the world."

Two examples demonstrate the advantages: With axial face seals that EagleBurgmann Germany inserted in pumps for critical environments, like the conveyors for oil, sand and gas mixtures, the diamond coating extends the durability for each application by a factor of 4 to 1,000. Drawing dies are a forming tool used in the production of wires. The unique feature here: the inner coating, which is possible through a modification of the process. This means that drawing dies can be coated for various diameters, allowing very thick wires to be realized, along with wires that are not circular at the cross-section. The test tools, which are used in production at the Elisental wire plant for example, were barely worn after several tons of wire had been produced.

Axial face seals for pumps have since been coated with diamonds by Condias GmbH, and marketed by EagleBurgmann in a variety of complex applications. Many other applications are also conceivable. „Ultimately, DiaCer® is of interest for all components in machine construction that need strong resistance to wear," summarizes Schäfer.

Project Partners:

– Fraunhofer Institute for Surface Engineering and Thin Films IST
– Fraunhofer Institute for Mechanics of Materials IWM
– Fraunhofer Institute for Ceramic Technologies and Systems IKTS
– Fraunhofer Institute for Production Systems and Design Technology IPK
– EagleBurgmann Germany GmbH & Co. KG
– Ceram Tec AG
– Condias GmbH
– Drahtwerk Elisental W. Erdmann GmbH & Co.
– Drahtzug Stein GmbH & Co. KG
– H.C. Starck Ceramics GmbH & Co. KG
– KSB AG

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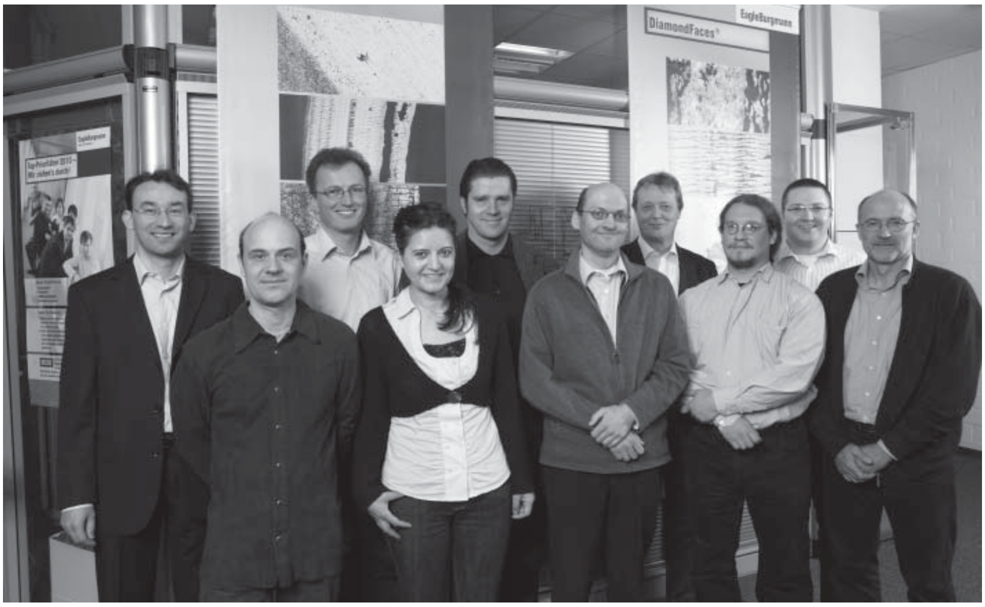
Dr. Simone Kondruweit, Dr. Lothar Schäfer, Dr. Markus Höfer, Markus Armgard of IST; the coatings and systems were designed there (from left to right). (© Fraunhofer / Dirk Mahler)

The ceramics specialists: Axel Bales, Dr. Mathias Herrmann, Kerstin Sempf (from left to right) (© Fraunhofer / Dirk Mahler)

Dr. Thomas Hollstein and Dr. Bernhard Blug provided important insights for the component simulations. (© Fraunhofer / Dirk Mahler)



EagleBurgmann markets the diamond-coated ring seals for critical environments.
(© EagleBurgmann Germany)

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High efficiency concentrator solar cells and moduls

Climate change and ever scarcer fossil resources will determine the energy mix of the future. Solar energy will play an integral role in this regard. Dr. Andreas Bett and Dr. Frank Dimroth of the Fraunhofer Institute for Solar Energy Systems ISE in Freiburg developed metamorphic triple-junction solar cell consisting of III-V compound semiconductors: gallium indium phosphide, gallium indium arsenide and germanium. This special structure makes it possible to optimize the use of almost the entire solar spectrum for energy production. Researchers have been able to transform more sunlight into power than ever before, at a record degree of efficiency of 41.1 percent. In recognition of their work, they are receiving the 2010 Joseph von Fraunhofer Prize.

This high degree of efficiency is made possible by stacking multiple top-quality solar cells on top of each other. „Our triple solar cell consists of more than 20 individual layers, all of which we have optimized," says Dr. Frank Dimroth. „We have improved both the structure of the semiconductor as well as the material quality, the metal contacts and the antireflection coatings, in order to arrive at this result." Originally, these compound solar cells were engineered for use in space - most satellites in space are loaded with them. They supply the operating power. Since the production process is comparatively expensive, these cells had not been used on earth before. The combination of highly efficient cells with a lens amplifier ensures that - in comparison to conventional solar modules - only one five-hundredth of the semiconductor surface will be needed. The cells within their own specially designed concentrator modules measure only three square millimeters in size. A Fresnel lens is situated over these mini solar cells, at a distance of approximately ten centimeters. This configuration concentrates the sunlight by a factor of 400 to 500. To prevent the cells from overheating, they are attached to a copper support that distributes the heat sufficiently well. Thus, passive cooling of the solar cells suffices. „Thanks to this construction, we were able to produce modules with a degree of efficiency in excess of 29 percent," says Dr. Andreas Bett. These modules have been on the market since 2007 under the brand name FLATCON®, and are being used in a solar park in Spain, for example.

To facilitate the swift transfer of technology from the laboratory to industry, a demonstration laboratory was constructed at the institute, with the same machines that would be used in industry. Here, researchers are developing and testing production processes for the construction and connection technology, module integration and quality control. A spin-off of ISE – Concentrix Solar GmbH – produces the concentrator systems that, for example, feed solar power into the grid from a solar park in

Spain with 25 percent system efficiency. For the development of metamorphic triple-junction solar cells, the team has been closely collaborating for years with AZUR Space Solar Power in Heilbronn, the leading European manufacturer of solar cells for space. This partner is aiming to bring the highly efficient solar cells to the market by 2011.

Dr. Andreas Bett and Dr. Frank Dimroth (left to right) working on highest-efficiency solar cells and concentrating solar modules to make solar energy cheaper. (© Fraunhofer / Dirk Mahler)

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Synthetic eye prosthesis

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For many patients who become blind after an accident or illness, a corneal transplantation could restore the ability to see. Each year, 40,000 people in Europe – in Germany, about 7,000 – await the opportunity to be able to see again, thanks to cornea donors. But donor corneas are not common. Dr. Joachim Storsberg of the Fraunhofer Institute for Applied Polymer Research IAP in Potsdam-Golm developed material and production process for a corneal prosthesis made of plastic. These can help patients who are unable to tolerate donor corneas due to the special circumstances of their disease, or whose donor corneas were likewise destroyed. In recognition of this accomplishment, Dr. Storsberg is being awarded the 2010 Joseph von Fraunhofer Prize.

The miniscale artificial cornea has to meet almost contradictory specifications: On the one hand, the material should grow firmly together with the cells of the surrounding tissue; on the other hand, no cells should settle in the optical region of the artificial cornea - i.e., the middle - since this would again severely impair the ability to see. And: The outer side of the implant must be able to moisten with tear fluids, otherwise the implant will cloud up on the anterior side. This would consequently require the patient to get a new prosthesis after a relatively brief period of time. And: The outer side of the implant must be able to moisten with tear fluid, so that the eyelid can slide across it without friction. Dr. Storsberg found the solution with a hydrophobic polymer material. This material has been in use for a long time in ophthalmology, such as for intraocular lenses. In order for it to satisfy the various characteristics required, complex development steps were necessary. The material was thoroughly modified on a polymer-chemical basis, and subsequently re-tested for public approval.

In order to achieve the desired characteristics, the edge of the implant was first coated with various, special polymers. Then, a special protein was added that contains the specific sequence of a growth factor. The surrounding natural cells detect this growth factor, are stimulated to propagate and populate the surface of the corneal margin. Thus, the cells of the surrounding tissue grow with the implant, and the artificial cornea attains stability. The eye prosthesis evolved jointly with physicians and manufacturers in the EU project, „Artificial Cornea." The interdisciplinary research team needed three years to develop the artificial cornea. In a first step, they sent the chemical-biomimetic coated implant to Dr. Karin Kobuch of the Poliklinik für Augenheilkunde at the Regensburg University Medical Center and to the medical center at the Technical University of Munich, on the right banks of the Isar river. The physician examined the artificial corneas in dissected pigs eyes and specialized cell cultures. Eventually, the team under Dr. Gernot Duncker and Dr. Saadettin Sel of the University Center for Ophthalmology in Halle (Saale) tested the more complex models in rabbits. There, the design was further refined: the optics were made smaller, and the implant haptic enlarged in order to maintain a more stable construction. Miro GmbH manufactured the implant, robin GmbH handled the distribution and sales and supported the specially adapted implantation centers in Europe. By 2009, a prosthesis was already successfully in use; further implantations are anticipated during the first six months of 2010.

Dr. Joachim Storsberg developed a synthetic corneal implant. (© Fraunhofer / Dirk Mahler)

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Sharkskin for airplanes, ships and wind energy plants

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The inspiration – and model – for the paint's structure comes from nature: The scales of fast-swimming sharks have evolved in a manner that significantly diminishes drag, or their resistance to the flow of currents. The challenge was to apply this knowledge to a paint that could withstand the extreme demands of aviation. Temperature fluctuations of -55 to +70 degrees Celsius; intensive UV radiation and high speeds. Yvonne Wilke, Dr. Volkmar Stenzel and Manfred Peschka of the Fraunhofer Institute for Manufacturing Engineering and Applied Materials Research IFAM in Bremen developed not only a paint that reduces aerodynamic drag, but also the associated manufacturing technology. In recognition of their achievement, the team is awarded the 2010 Joseph von Fraunhofer Prize.

The paint involves of a sophisticated formulation. An integral part of the recipe: the nanoparticles, which ensure that the paint withstands UV radiation, temperature change and mechanical loads, on an enduring basis. „Paint offers more advantages," explains Dr. Volkmar Stenzel. „It is applied as the outermost coating on the plane, so that no other layer of material is required. It adds no additional weight, and even when the airplane is stripped – about every five years, the paint has to be completely removed and reapplied – no additional costs are incurred. In addition, it can be applied to complex three-dimensional surfaces without a problem." The next step was to clarify how the paint could be put to practical use on a production scale. „Our solution consisted of not applying the paint directly, but instead through a stencil," says Manfred Peschka. This gives the paint its sharkskin structure. The unique challenge was to apply the fluid paint evenly in a thin layer on the stencil, and at the same time ensure that it can again be detached from the base even after UV radiation, which is required for hardening.

When applied to every airplane every year throughout the world, the paint could save a volume of 4.48 million tons of fuel. This also applies to ships: The team was able to reduce wall friction by more than five percent in a test with a ship construction testing facility. Extrapolated over one year, that means a potential savings of 2,000 tons of fuel for a large container ship. With this application, the algae or muscles that attach to the hull of a ship only complicate things further. Researchers are working on two solutions for the problem. Yvonne Wilke explains: „One possibility exists in structuring the paint in such a way that fouling organisms cannot get a firm grasp and are simply washed away at high speeds, for example. The second option aims at integrating an anti-fouling element – which is incompatible for nature."

Irrespective of the fuel savings, there are even more interesting applications – for instance, with wind energy farms. Here as well, air resistance has a negative effect on the rotor blades. The new paint would improve the degree of efficiency of the systems – and thus the energy gain.

Yvonne Wilke, Dr. Volkmar Stenzel and Manfred Peschka engineered a paint system that can reduce the flow resistance of airplanes and ships. That saves fuel. (© Fraunhofer / Dirk Mahler)

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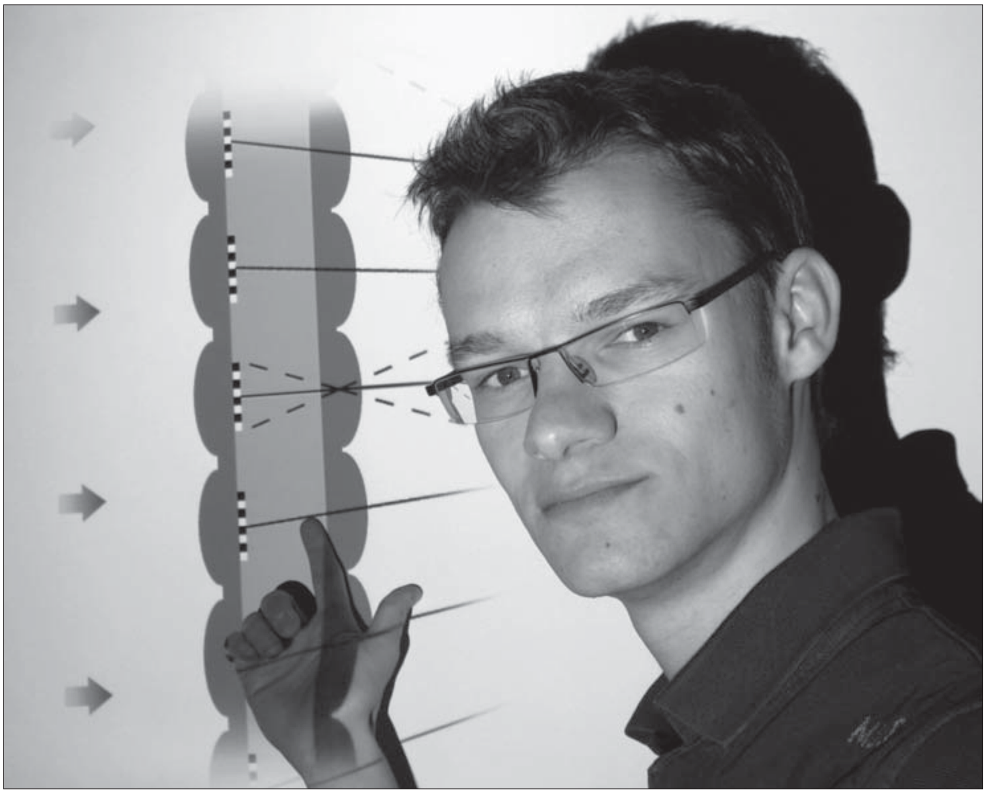
Mini-projectors – maximum performance

Almost no public presentation today is made without projectors. As the years pass, these devices keep getting smaller – and handier. A market with immense growth potential: According to estimates, by 2012 up to 45 million units are expected to sell worldwide. Important: The miniature projectors have to deliver sharp contrasts and clear colors. In his thesis project, „Design and realization of an ultraflat array projector," Marcel Sieler of the Fraunhofer Institute for Applied Optics and Precision Engineering IOF in Jena developed the bases for an entirely new kind of design in order to realize mini-projectors. In recognition of this, he is awarded the 1st Hugo Geiger Prize.

In all current systems of pocket projectors, a single imaging channel is used. This means a minimal size for the projector is a given – and smaller will not work. Except for Marcel Sieler: His construction method relies on a number of regularly ordered micro-lenses – an array – as the projection lens. Thanks to the many channels, the construction length of the entire system can be clearly reduced, without impeding luminosity. A high-performance LED is used as the light source.

In order to achieve this result, in his thesis project, Sieler initially tested and adapted the theoretical basis for the construction of a micro-lens array. He then devised a corresponding system that was characterized in laboratory experiments and tested for its optical performance capacity. Within nine months, Marcel Sieler transformed his idea into the first prototypes. With these, he could display the immense potential of the concept with which both static as well as mobile image contents can be projected. This project required competence in optical design, in microsystem technology - as well as in project management, strength of purpose and personal commitment. Based on Marcel Sieler's work, the Fraunhofer-Gesellschaft was able to apply for a basic patent for this new kind of optical system.



Marcel Sieler analyzed ultraslim array projectors, realized an initial prototype and thereby opened up the path to the new mini-projectors. (© private)

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Material with potential

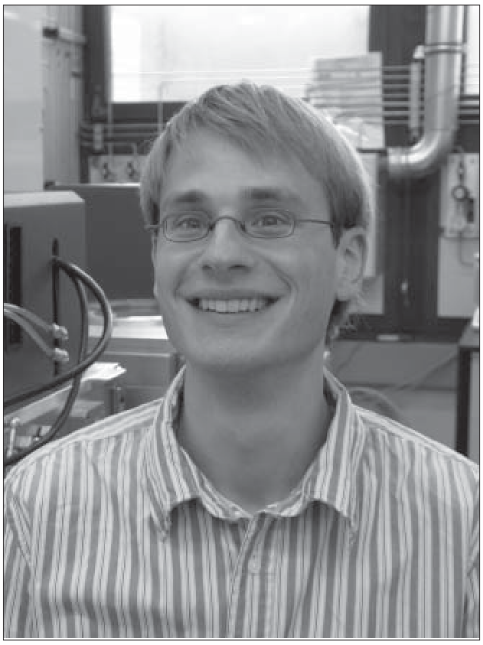
Silicon carbide (4H-SiC) is the ideal semiconductor material for power electronics. For instance, efficient power converters for electric vehicles or photovoltaic systems can be produced - as well as electronics that work at high temperatures. Until now, however, very few electron devices made of silicon carbide are on the market. The reason for this: The quality of the crystals and epitaxial layers is not yet sufficient for the demanding applications because even the slightest material defects, in form of dislocations, can lead to a malfunction of the component. Dislocations are deviations from the ideal crystal lattice structure, which may occur in different types.

In his thesis project, „Structural defect characterization of 4H-SiC substrates and epitaxial layers using x-ray topography and x-ray diffractometry," Sebastian Polster of the Fraunhofer Institute for Integrated Systems and Device Technology IISB studied these dislocations. He compared the type and number of these crystalline defects using x-ray images that he recorded with the ANKA synchrotron source, with images that were prepared using the conventional etching technique in the laboratory. In this manner, he succeeded in depicting the limits of the established characterization method. The results of this method can now be interpreted with certainty. This is an important basis in order to improve the material regarding the avoidance of critical dislocation types in the material, so that electron devices based on SiC can dominate their market. In recognition of his accomplishments, Sebastian Polster is awarded the 2nd Hugo Geiger Prize.

Growing through holes

An important objective of solar cell research is to produce photovoltaic modules inexpensively, in order to make the power it produces competitive with conventional energy resources. One potential concept to achieve this is the use of crystalline thin-film solar cells, which come from a very thin layer of the expensive, ultrapure silicon. Another option can be found in solar cells whose current-collecting contacts are situated only on the back side of the solar cells, laden with via holes.. Physicist Nils Brinkmann of the Fraunhofer Institute for Solar Energy Systems ISE showed in his thesis project, „Epitaxy through holes: Process development and characterization," how the advantages of both varieties can be brought together.

One decisive factor in the new cell concept: minute via holes. The epitaxial layers grow through these on both sides of the thin silicon substrate. This completely new approach was developed by Nils Brinkmann with the aid of Simulations that he then applied in a production process. In addition, he showed how the degree of efficiency of the new solar cells can be further optimized. Nils Brinkmann is awarded the 3rd Hugo Geiger Prize.



Sebastian Polster and Nils Brinkmann (left to right) were recognized for their thesis projects. (© private)

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