Fraunhofer FEP

Fraunhofer Institute for
Organic Electronics, Electron Beam
and Plasma Technology FEP

Annual Report 2021/22

Content

Prof. Dr. Elizabeth von Hauff,
Director of Fraunhofer FEP

Foreword

Dear partners of the Fraunhofer FEP,
dear readers,

2021 was a year of new beginnings for the Fraunhofer FEP and featured many high points despite the ongoing pandemic situation.

In May, the research teams from the Fraunhofer Institutes IZI, IPA, and FEP were awarded the Joseph von Fraunhofer Prize for the development of a more efficient, faster, and more ecological vaccine manufacturing process. In addition, Philipp Wartenberg, head of the IC and System Design department, received the Fraunhofer-Gesellschaft Executive Board's Excellence Award for his outstanding work in the dynamic research field of OLED microdisplays. In addition to innovative technological approaches, he succeeded in obtaining funding for several complex, multi-million-Euro industrial projects, thus considerably strengthening our networking with national as well as international partners and helping place the Institute in the top of this field internationally.

In June 2021, Prof. Elizabeth von Hauff joined Institute Director Prof. Volker Kirchhoff as Co-Director of the Fraunhofer FEP. After more than 25 years as Institute Director and a six-month transition period, Prof. Kirchhoff bid the Fraunhofer FEP farewell and retired. We wish to express our gratitude to him for the work he has done in building the Fraunhofer FEP into a well-functioning and efficient institute and guiding it over these many years. In addition, Prof. von Hauff has been appointed to the TU Dresden's Professorial Chair for Coating Technologies in Electronics. The appointment of Dr. Gösta Mattausch as Honorary Professor for Electron Beam Technology at the University of Applied Sciences Zwickau further strengthened the Institute's network in the Saxony university landscape.

The Institute's many years of expertise in the continuously developing field of electron-beam technology led to founding E-VITA GmbH as a joint venture with Ceravis AG. The spin-off is dedicated to non-toxic, sustainable dressing of seed and animal feed to rid them of pathogenic fungi, bacteria, and viruses. We have already received a major order from E-VITA GmbH that proved to be the Fraunhofer-Gesellschaft's largest outside R&D contract for October.

»I am looking forward to my new work as Executive Director of the Fraunhofer FEP and university lecturer at TU Dresden. My aim is to strengthen the collaboration between the two institutions, but also with other institutes and industrial partners. I hope that this will provide new impetus – not least for Dresden and Saxony.«

Prof. Dr. Elizabeth von Hauff,
Director of Fraunhofer FEP

Staff in all other business units of the Institute also worked on numerous regional, national, and EU projects, such as sophisticated coating processes for improving attraction and absorption of ions and moisture by zeolite granules, and developed industrial real-time and in-line technologies for characterizing nanomaterials. In the field of medical and biotechnological applications, the broad base of our expertise and technologies was employed to work on solutions for inactivating pathogens, such as using UVC to sterilize touch screens, among other things.

The numerous application-oriented projects for solving industrial problems using our technologies have been accompanied by the continuous structural expansion of the institute for several years. For example, construction of a new building to expand the Institute's infrastructure (including future laboratory capacity, engineering, and clean room) began in 2019 at the FEP's Bodenbacher Straße location in Dresden, with completion and commissioning expected in 2022. We are also proud to have gained 34 new employees this year – including many young people, such as trainees.

Despite the continuing unpredictable Corona situation, we were nevertheless able to expand our balance sheet, achieved a very good bottom line, and acquired numerous new projects in 2021. Based on this positive news, we look confidently to the future of the Institute. At this point, we offer our special thanks to all our employees as well as to our funding sponsors and partners from industry for their continued substantial trust!

We have compiled for you some of the projects and topics mentioned above and hope that this annual report sparks ideas for new mutually beneficial joint projects.

We hope you enjoy reading it and look forward to continued win-win collaboration!

Contact Persons

Prof. Dr. Elizabeth von Hauff

Director

Phone +49 351 2586-0
elizabeth.von.hauff@fep.fraunhofer.de

Veit Mittag

Head of Administration

Phone +49 351 2586-405
veit.mittag@fep.fraunhofer.de

Ines Schedwill

Marketing

Phone +49 351 8832-238
ines.schedwill@fep.fraunhofer.de

Annett Arnold

Corporate Communications

Phone +49 351 2586-452
annett.arnold@fep.fraunhofer.de

Dr. Burkhard Zimmermann

Division Electron Beam Sources – Processes – Applications

Phone +49 351 2586-386
burkhard.zimmermann@fep.fraunhofer.de

Dr. Ulla König

Division Medical and Biotechnological Applications

Phone +49 351 2586-360
ulla.koenig@fep.fraunhofer.de

Dr. Nicolas Schiller

Division Plasma Technology

Phone +49 351 2586-131
nicolas.schiller@fep.fraunhofer.de

Dr. Christian May

Division Flexible Organic Electronics

Phone +49 351 2586-220
christian.may@fep.fraunhofer.de

Dr. Uwe Vogel

Division Microdisplays and Sensors

Phone +49 351 2586-160
uwe.vogel@fep.fraunhofer.de

Dr. Michiel Top

Division Systems

Phone +49 351 2586-355
michiel.top@fep.fraunhofer.de

Advisory Board

Chairmen of the Board

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Merck KGaA, Global Head of Group Corporate Sustainability
Chairman of the Board

Dipl.-Ing. Ralf Kretzschmar
Belimed Life Science AG, Chief Executive Officer
Deputy Chairman of the Board

Foto der 30. Kuratoriumssitzung am 14. Mai 2019. Im Jahr 2020 und 2021 fand die Sitzung virtuell statt.

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ALD Vacuum Technologies GmbH, Technischer Geschäftsführer

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Universität Leipzig, Medizinische Fakultät, Institut für Pharmazie, Lehrstuhl für Pharmazeutische Technologie

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VON ARDENNE GmbH, Member of Executive Management

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Referatsleiter Technologiepolitik, Technologieförderung

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Dr. Ulrich Engel
Former Chairman of the Board

Dr. Patrick Hoyer
Fraunhofer-Gesellschaft, Institute Liaison

Dr. Hans-Ulrich Wiese
Former Member of the Board of the Fraunhofer-Gesellschaft

This list represents the status as of year-end 2021. For an up-to-date version, please visit our website at:

https://s.fhg.de/NX2

Organizational Structure

Fraunhofer FEP

Directors
Prof. Dr. Elizabeth von Hauff
Prof. Dr. Volker Kirchhoff

Corporate Communications – Annett Arnold
Marketing – Ines Schedwill
Team Assistance – Mandy Schreiber
Administration – Veit Mittag
Information Technology – Udo Gernandt
Quality / Knowledge Management – Sabine Nolting
Protective Rights / Contracts – Jörg Kubusch
Technical Management – Gerd Obenaus

Electron Beam Sources – Processes – Applications – Prof. Dr. Chr. Metzner
- **Coating Metal, Energy Applications, Parts and Cleaning** – Dr. Torsten Kopte
- **Coating Metal and Energy Applications** – Dr. Torsten Kopte
- **Cleaning** – Frank-Holm Rögner
- **Coating of Parts** – Dr. Fred Fietzke
- **Customized Electron Beam Systems and Technologies** – Prof. Dr. Gösta Mattausch

Medical and Biotechnological Applications – Dr. Ulla König
- **Hygienization and Biofunctionalization** – Dr. Gaby Gotzmann
- **Tissue Banking and Cell Therapy** – Dr. Ulla König
- **Biotechnological Processes** – Dr. Simone Schopf

Plasma Technology – Dr. Nicolas Schiller
- **R2R Technologies** – Dr. Matthias Fahland
- **R2R High-Rate Vacuum Coating** – Steffen Straach
- **R2R Sputtering and PECVD** – Dr. John Fahlteich
- **R2R Wet Coating and Electron Beam Curing** – Dr. Steffen Günther
- **S2S Technologies and Precision Coating** – Dr. Hagen Bartzsch
- **S2S Sputtering and PECVD** – Dr. Kerstin Täschner
- **Dynamic Precision Coating** – Dr. Daniel Glöß
- **Static Precision Coating** – Dr. Stephan Barth
- **Sputterepitaxy Technologies** – Dr. Alexander Hinz

Flexible Organic Electronics – Dr. Christian May
- **S2S Organic Technology** – Claudia Keibler-Willner
- **Organic Cleanroom** – Carsten Kirmes
- **R2R Organic Technology** – Dr. Christian May

Microdisplays and Sensors – Dr. Uwe Vogel
- **Organic Microelectronic Devices** – Bernd Richter
- **IC and System Design** – Philipp Wartenberg
- **Microdisplay Cleanroom** – Mario Metzner

Systems – Dr. Michiel Top
- **Mechanic Development** – Henrik Flaske
- **Electronic Development** – Rainer Labitzke
- **Prototyping** – Mirko Kreusel
- **Materials Analysis** – Dr. Olaf Zywitzki

Division | Department | Group

The organizational structure shown represents the status as of 08/2021. A current version can be found on our website at:

https://s.fhg.de/5a3

The Institute in Figures

Financing

Fraunhofer FEP was able to bring in 11.5 million € of new business from industry through direct contracts. Proceeds of 9.8 million € were obtained from public projects funded by the federal and state governments. A portion of these, amounting to 4.6 million €, was attracted through joint publicly funded projects with mid-cap companies. The expenditure of institutional capital ran to 7.6 million €.

Investment costs

Total expenditures from the operating and investment budget amounted to 28.8 million €. 1.3 million € was invested in equipment, construction and infrastructure during the period.

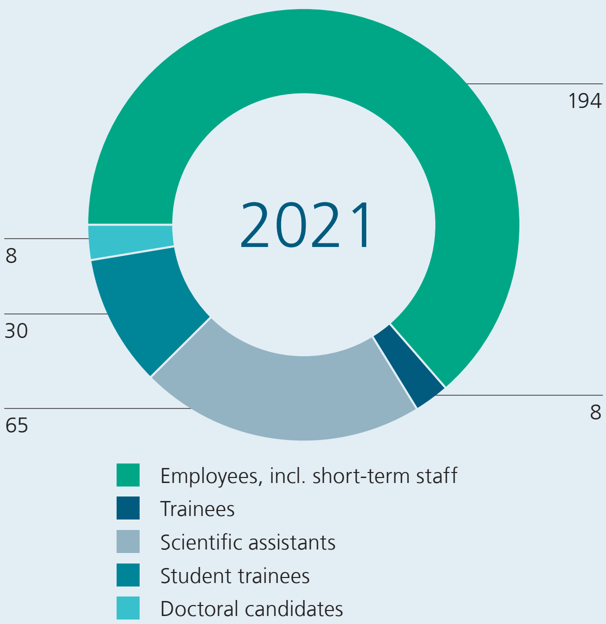
Staff and material costs

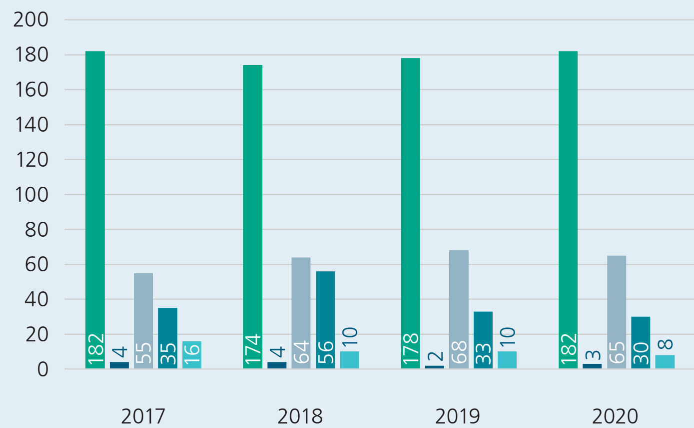
Personnel expenditures totaled 13.9 million €, representing 50.5 percent of the operating budget (27.5 million €). Material costs amounted to 11.5 million €.

Employee development

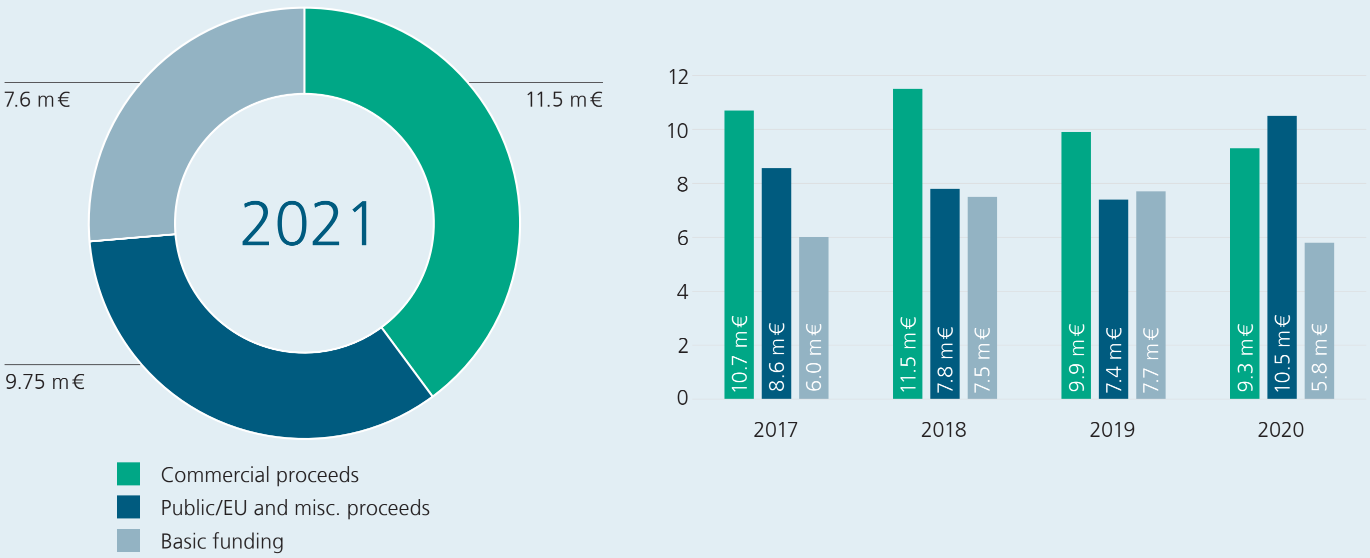
194 staff members were employed at the institute during the past year, of which 8 were trainees, along with 30 student trainees as well as 65 scientific assistants. Of the 72 staff members that were employed as scientists, 15 were additionally working on their doctoral degrees. The proportion of females in the scientific area amounted to 23 percent.

Employee development

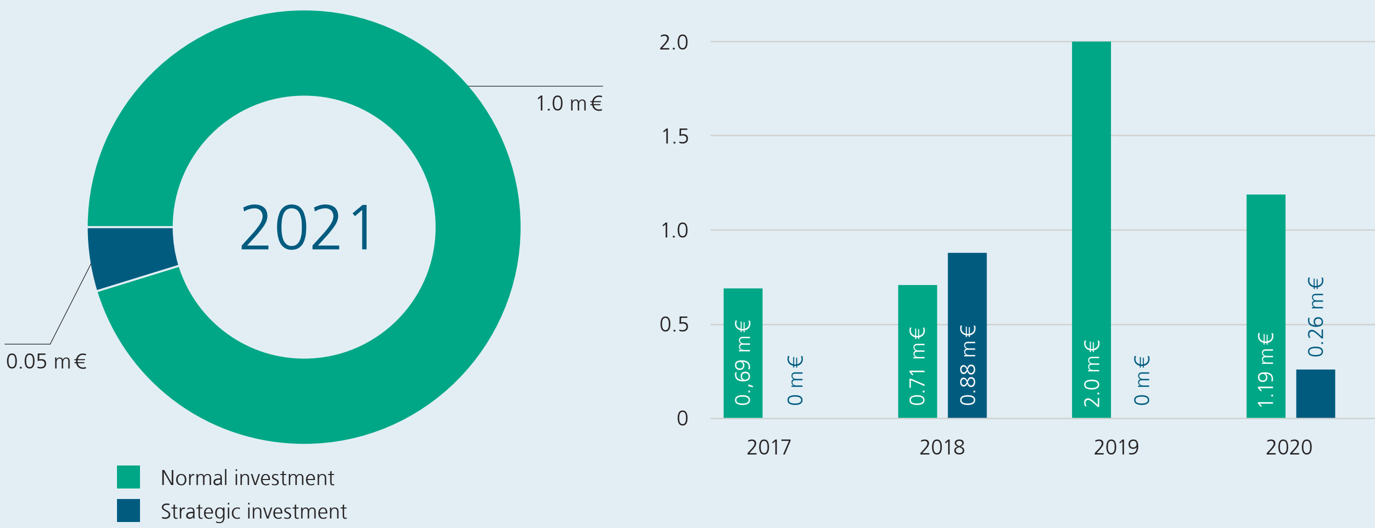




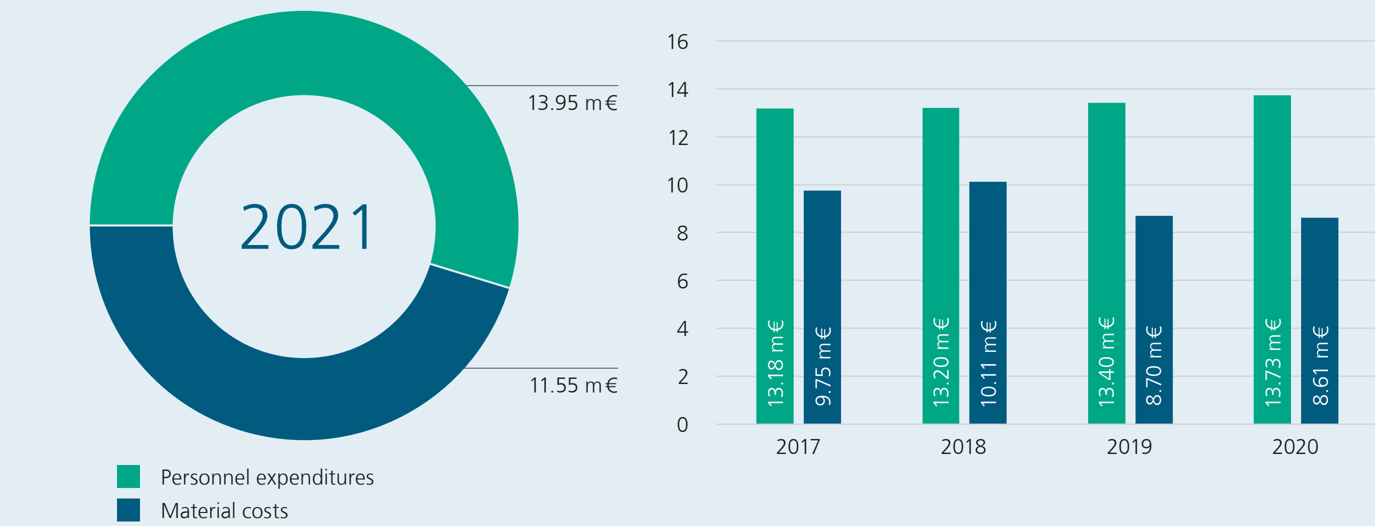
Financing



Investment costs



Staff and material costs



Research News

Business Units

Dr. Fred Fietzke

Coating of Parts

Phone +49 351 2586-366
fred.fietzke@fep.fraunhofer.de

Dr. Torsten Kopte

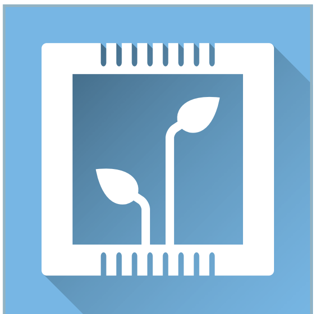
Coating of Metal Sheets and Strips, Energy Technologies

Phone +49 351 2586-120
torsten.kopte@fep.fraunhofer.de

Prof. Dr. Gösta Mattausch

Development of Customized Electron Beam Systems and Technologies

Phone +49 351 2586-202
goesta.mattausch@fep.fraunhofer.de



Dr. Christian May

Flexible Organic Electronics

Phone +49 351 2586-220
christian.may@fep.fraunhofer.de

Dr. Matthias Fahland

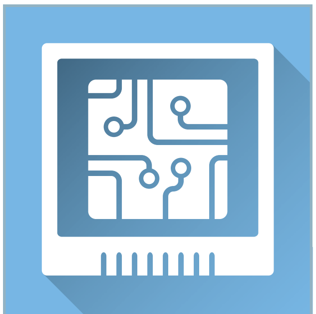
Flexible Products

Phone +49 351 2586-135
matthias.fahland@fep.fraunhofer.de

Dr. Ulla König

Medical and Biotechnological Applications

Phone +49 351 2586-360
ulla.koenig@fep.fraunhofer.de



Dr. Uwe Vogel

Microdisplays and Sensors

Phone +49 351 2586-160
uwe.vogel@fep.fraunhofer.de

Dr. Hagen Bartzsch

Precision Coating

Phone +49 351 2586-390
hagen.bartzsch@fep.fraunhofer.de

Coating of Components

Physical vapor deposition (PVD), used for coatings on tools and components to provide low friction, wear reduction, as well as corrosion protection, has a long tradition at Fraunhofer FEP. Coatings with specific optical and electrical properties, biochemical compatibility, as well as scratch and abrasion resistance are also available for applications in the consumer goods industry as well as in the fields of energy and medical technology.

Ever higher demands are being placed on coatings and process development today, and limiting factors such as thermal load capacity of the substrate materials, the complex shape and structure of certain components, and the surface roughness of additively manufactured parts must always be taken into account. An additional focus at Fraunhofer FEP is coating small parts in bulk to achieve corrosion protection of joining elements or functionalization of metallic, ceramic, or glassy granulates and powders.

High-deposition-rate electron beam and thermal evaporation are used as coating technologies in addition to pulse magnetron sputtering in single, double, and multi-source configurations. An additional area of concentration is the development and application of plasma sources for substrate pre-treatment as well as for physical and chemical vapor deposition.

Aluminum-based corrosion protection for the aerospace industry

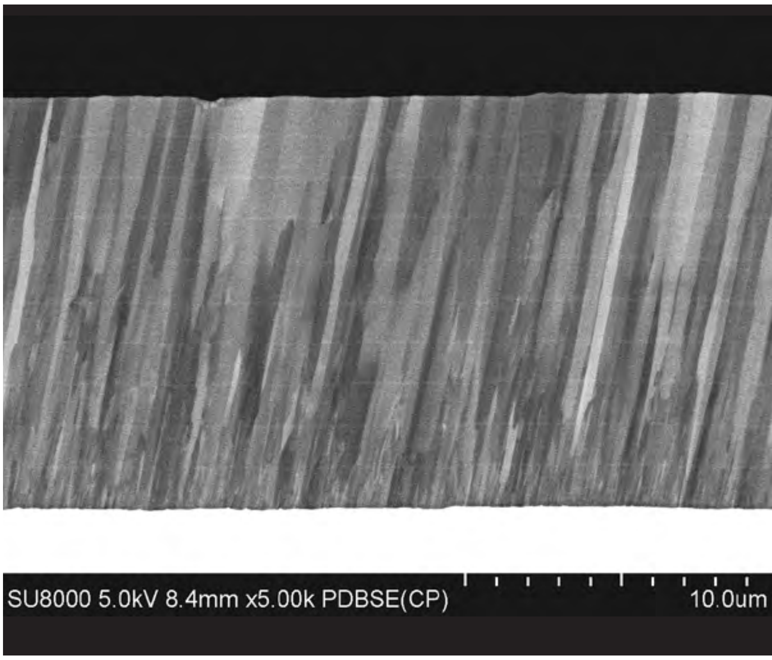
Contact: Dr. Fred Fietzke | Phone +49 351 2586-366 | fred.fietzke@fep.fraunhofer.de

In the ProAlu project, research institutions and companies have joined forces to develop aluminum-based anti-corrosion coatings for aerospace.
The Fraunhofer FEP is involved with vapor-deposited and sputtered multilayer coatings.

Corrosion continues to be a problem affecting all industrial sectors and causes economic losses exceeding 100 million Euros annually in Germany alone. Increased environmental and human-health protection requirements under European REACH regulations that favor lightweight construction and alternative power and drive systems have necessitated replacement of materials that have been employed for decades, such as cadmium and hexavalent chromium, to achieve more effective protection.

In the aerospace industry, where predominantly aluminum-based materials are used, as well as high-strength structural and joining components made of steel or titanium, the focus of development is therefore on corrosion protection coatings made of aluminum combined with suitable alloying elements. The ProAlu project funded by the German government is investigating the extent to which self-passivation of aluminum can be suppressed by adding small quantities of a more noble metal, thereby providing the aluminum with cathodic protection, i.e. slower self-dissolution in favor of the underlying structural material – analogous to zinc coatings. Efforts here are concentrated on the addition of tin, which is advantageous not only from the electrochemical but also from the materials engineering point of view because it does not form mixed phases with aluminum. However, tin's low melting temperature and strong tendency to diffuse pose challenges for PVD processes that can only be met by specially adapted process management.

Multilayer coatings of plasma-activated vapor-deposited pure aluminum with thin intermediate layers of sputtered aluminum-tin alloy have proven to be particularly advantageous. Now that their development potential has been demonstrated in electrochemical tests by participating project partners, long-term tests of the corrosion protection as well as the extrapolation of results obtained with flat samples to components and fasteners that can be coated as bulk material are on the agenda.



Cross-section of a multilayer corrosion protection coating made of aluminum and tin
© Fraunhofer FEP

The project is continuing and will run until September 2023.

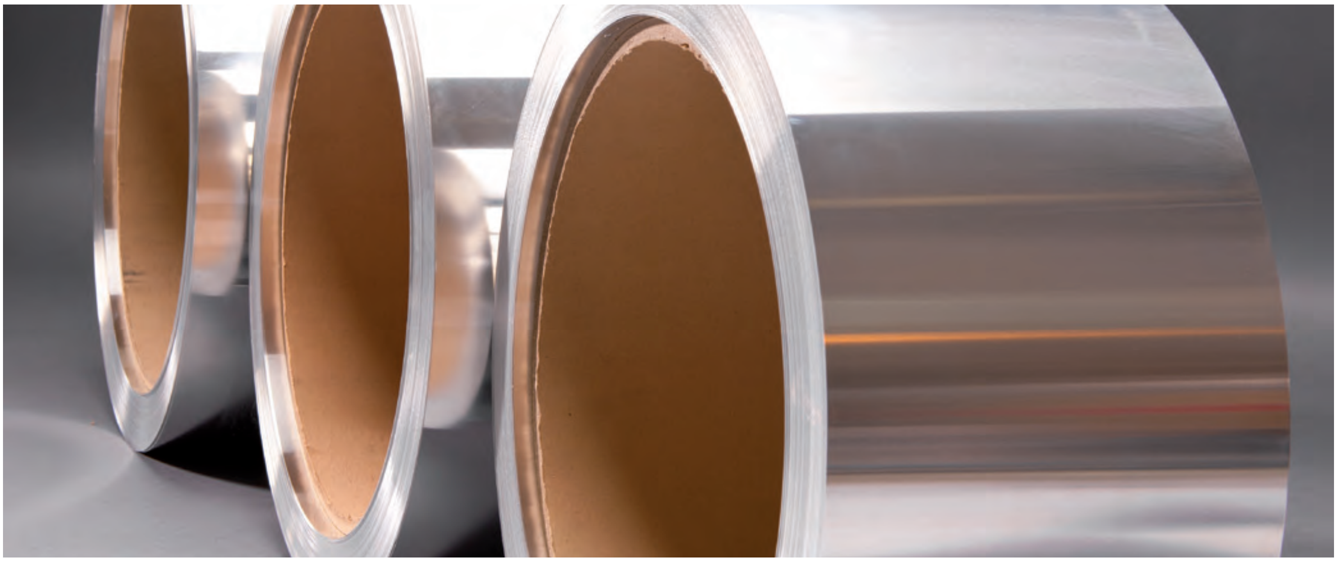
Supported by:
Federal Ministry for Economic Affairs and Energy

Funded under the German government's aeronautics research program (LuFo). Funding reference: 20W1921F

Coating of Metal Sheets and Strips, Energy Technologies

The business unit comprises the vacuum coating of metallic sheets and strip for a wide variety of applications in the fields of mechanical engineering, architecture, packaging, transportation, lighting, and the environment. Anti-corrosion coatings based on zinc, tin, and aluminum represent one of our classic fields of activity in the area of steel strip coating. In the field of power engineering, we deal with various application areas such as photovoltaics, and the transport and storage of electrical energy. We develop technologies for depositing thin functional layers suited to high-performance solar cells, low-loss electrical cables, and electrical-energy storage systems.

Vacuum deposition processes are predominantly used in this business unit, as high areal throughput and extremely economical processes with high deposition rates are usually required for the coating of metallic sheets and strip. To improve the coating properties, special plasma activation processes for evaporation have been developed and adapted to coating large areas at these high deposition rates. The »MAXI« inline vacuum coating system for metallic sheets and strip is available as a prototyping and pilot-production system.



nextBatt – Production processes for next-generation battery anodes using a minimum of natural resources

Contact: Dr. Torsten Kopte | Phone +49 351 2586-120 | torsten.kopte@fep.fraunhofer.de

The nextBatt project was initiated and carried out by a Fraunhofer-Gesellschaft consortium of FEP, IWS, ISE, and IST.
The goal was to create technological foundations for new battery-anode manufacturing processes that consume a minimum of natural resources.

Evaporation crucible with lithium granules
© Fraunhofer FEP

The nextBatt project comprised a number of work packages covering the topic of next-generation battery anodes. Staff of the Coating of Metal Sheets and Strips, Energy Technologies business unit devoted themselves to the challenge of creating pure metallic lithium layers using physical vapor deposition. The goal was to carry out fundamental investigations into the applicability of thermal evaporation for the deposition of lithium at high coating rates and high areal throughput.

Dealing with the extremely high reactivity of lithium is very challenging. It reacts not only with oxygen in the air, but also with nitrogen. Lithium binds with water to form strongly basic lithium hydroxide while generating free hydrogen. This reaction is strongly exothermic. It is clear that working with lithium requires special occupational safety measures. Moreover, lithium can only be handled in an inert atmosphere. For this purpose, the glove box at the coating facility was first purged with then filled with anhydrous argon. This made the facility usable for experiments with materials that react with air, especially lithium. Expertise in handling these materials has been expanded.

The simplest possible semi-continuous feeding of deposition materials is important for industrial applications of evaporative deposition processes. As lithium is also commercially available as granules, an evacuated demand-driven material handling system was created to feed them to the evaporator.

This allowed coating experiments to be carried out and lithium was successfully deposited on metallic sheet and thin copper foil. A deposition rate of up to 120 nm/s was demonstrated, which corresponded to a dynamic deposition rate of about 1 µm m/min in the coating configuration used.

The deposited lithium coatings were investigated for their performance in battery applications at our partner Fraunhofer Institutes ISE and IWS. These investigations delivered promising results regarding battery capacity and charging-cycle stability.

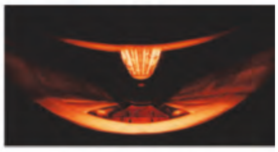
Development of Customized Electron Beam Systems and Technologies

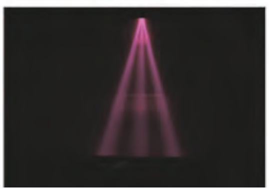
Electron beams are exceptionally versatile tools for the processing of materials, surface refinement, environmental technology, medical as well as technical imaging, inline process control and analytics. They combine a wealth of physical, chemical and biological effects with high energetic efficiency, excellent precision and outstanding technological flexibility. The intense, locally and temporally precisely controlled heating of solids by focused electron beams can be used to advantage for welding, micro-structuring and vaporization (at the highest rates technically achievable) as well as for additive manufacturing and machining of complex components. Chemical effects bring about energy-efficient and highly productive curing of paints, modification of plastics, plasma-chemical syntheses, and pollutant removal in wastewaters and exhaust gases. The biological effects include antimicrobial and fungicidal actions. In this way, medical products such as tools and packaging can be safely sterilized. The chemical-free disinfection of seeds is another application example with high ecological relevance. Furthermore, electron treatment can also be used for biocompatible functionalization of implants and stimulation of biotechnological processes.

In this multifaceted business field, we develop electron beam sources as well as their control and supply systems optimized for different customer requirements and tasks, but also qualify new electron beam processes for innovative applications in research and production. The aim is to provide our customers with application-ready integrated packages – advanced technologies and systems from a single source.





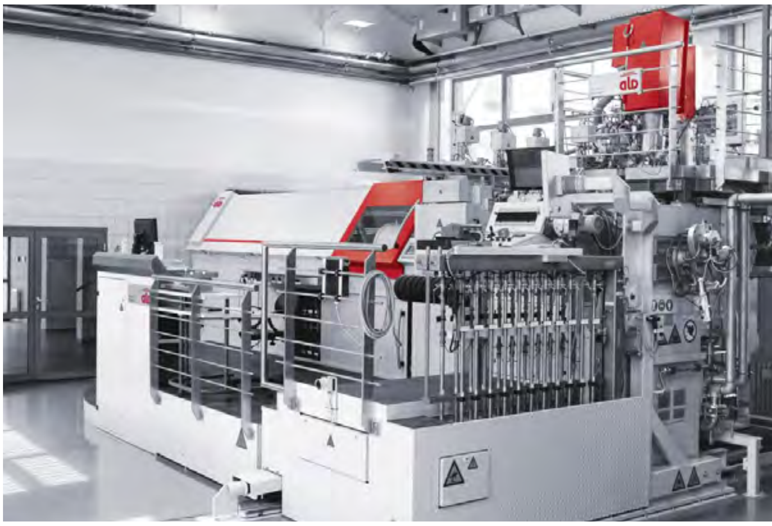



Tandem Hollow Cathode Module for Plasma-Activated Coating of Turbine Blades in a SMART Coater

Contact: Prof. Dr. Gösta Mattausch | Phone +49 351 2586-202 | goesta.mattausch@fep.fraunhofer.de

By implementing a hollow cathode module in its SMART Coater pilot plant, ALD Vacuum Technologies together with Fraunhofer FEP has created a production-level development platform for plasma-activated EB-PVD technologies and coatings for next-generation aero engines.



Pilot production facility and platform for the development of EB-PVD technologies for turbine blade coating at Rzeszow University of Technology
© ALD Vacuum Technologies GmbH

Modern passenger aircrafts have made humankind's age-old dream of flying come true and today connect all the continents of the world in just a few hours. At the same time, however, aviation is facing the challenge of sustainably reducing its CO_2 emissions. The keys to this are to further increase the efficiency of new aero engine generations and to make them compatible with »green« fuels. Coating technology can significantly contribute to achieving these goals.

For more than 30 years, yttrium-stabilized zirconia (YSZ) has been used as a ceramic thermal barrier coating (TBC) on turbine blades to increase the operating temperatures of the engines and reduce fuel consumption. EB-PVD has established itself as the vacuum coating process of choice, especially for components in the most highly stressed sections of turbines. EB-PVD delivers, at a high growth rate, uniform coatings with a dendritic structure and well-anchored footholds as well as dense and smooth surfaces.

New engine concepts and non-fossil fuels now aim at further lowering the thermal conductivity and increasing the service life of TBC coatings, increased chemical resistance (e. g. against volcanic ash, CMAS) and the protection of non-metallic lightweight components (carbon matrix composites, CMC) against environmental influences (environmental barrier coatings, EBC). This requires more complex layer systems, whereby in addition to the composition, their defined morphology always plays a decisive role, which for economic reasons should also be achieved at increased coating rates, elevated process pressures and reduced substrate temperatures.

Fraunhofer FEP's many years of development and expertise in this field of work led to the expectation that such requirements could be met by activating the EB-PVD process, i. e. ionization and excitation of the layer-forming species by means of dense arc discharge plasmas. Due to the great interest of end users, the equipment manufacturer ALD Vacuum Technologies GmbH therefore contracted Fraunhofer FEP to develop a pulsed tandem hollow cathode module and provided a test platform for its integration and subsequent technological trials.
The choice fell on ALD's SMART Coater pilot plant, which is operated at the Technical University of Rzeszow (Poland) and used to qualify new coating processes and layer systems. An important criterion here is the subsequent transferability of the technology to ALD`s large-scale production plants.

The transfer, commissioning and performance verification of the new plasma activation module for the SMART Coater were completed on schedule despite difficult conditions due to the COVID pandemic. This success was made possible to a large extent by the harmoniously cooperating teams of ALD and Fraunhofer FEP formed over already fifteen years of collaboration in previous projects, as well as great support from the Technical University of Rzeszow. The first results shall be presented at the Thermal Barrier Coatings conference in Irsee (Germany) in June 2022.

Flexible Organic Electronics

Technologies, processes, and applications for devices with organic semiconductors are the focus of development work in this business unit. For customer-specific research projects, we offer a comprehensive range of services spanning the entire value chain for organic light-emitting diodes, organic photodiodes, organic field-effect transistors, organic and perovskite solar cells, and biodegradable electronics, especially on larger areas.

Various deposition technologies are available for this purpose, such as vacuum evaporation, atomic-layer deposition, as well as printing, lamination, and laser etching processes. Development is taking place using individual as well as roll-to-roll substrates and involves the fabrication of demonstrators and evaluation of materials and processes.

The EU-funded innovation hub PhotonHub Europe has started 2021. The participating institutions plan to pool European-wide expertise, technology know-how, and equipment to accelerate the application of photonics technologies by European industry. We will support the innovation activities of PhotonHub Europe with our know-how along the entire value chain for organic large-area electronic devices.

Biodegradable RFID antennas

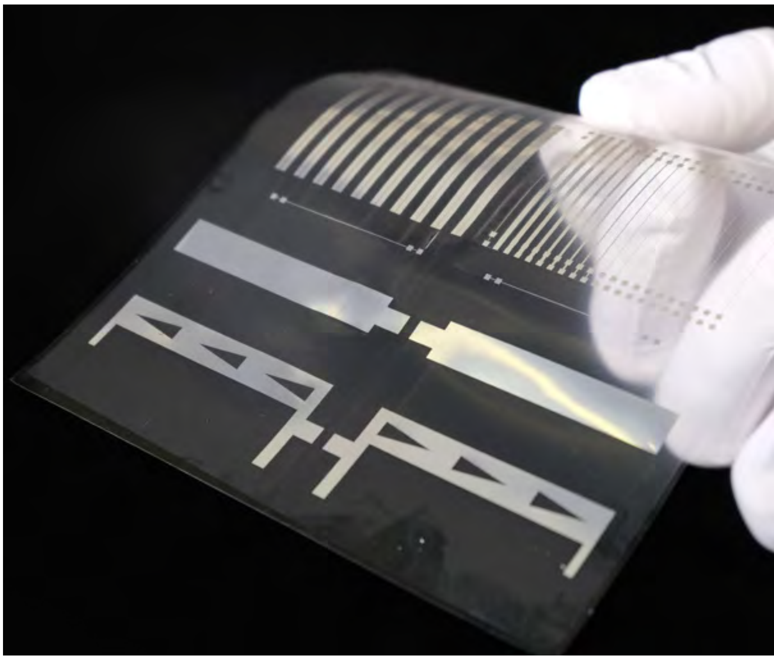
Contact: Dr. Christian May | Phone +49 351 2586-220 | christian.may@fep.fraunhofer.de

The »Bio-based Tag« project successfully evaluated the feasibility of vacuum-deposited magnesium antenna structures on bio-based and biodegradable substrates for use in RFID transponders..

Current research and development activities intend to create not only bio-based but also biodegradable packaging techniques. However, this does not yet take into account the various mechanisms used in merchandise management to identify goods, such as single-use passive RFID transponders. Due to the increasing use of transponders, the number of transponders that are no longer used and end up in the trash is also increasing. Currently, these transponder systems are made from non-biobased polymer films as substrates, most of which have an electro-deposited aluminum layer.

The goal is to develop an RFID transponder that has a considerably reduced environmental footprint compared to those currently marketed. The proportion of bio-based materials will be substantially increased and the overall product will be both easily reusable as well as biodegradable. Our approach addresses the material-intensive components, substrate, and conductor structures, especially the antenna. The central strategy is to use the rapidly degradable and biologically harmless magnesium to replace the aluminum metal used in the conventional product.

Studies of the technical feasibility have shown that the scalable vacuum-deposition process established at the Fraunhofer FEP can be used to deposit the magnesium antenna material as intended on various commercial bio-based and biodegradable substrate materials. The conductivities achieved are on the order of bulk conductivity, and sheet resistivities of 0.2-0.5 ohm/sq are achieved with current film thicknesses of 200 nm. Patterning the antenna material using shadow masks is feasible, or for potentially desired deposition processes also by laser ablation.



Biodegradable Mg-based antenna patterns
© Fraunhofer FEP

Vacuum deposition of the antenna design makes RFID transponders more ecological. The next efforts will focus on scaling up to roll-to-roll technology.

Supported by:

Federal Ministry
of Education
and Research

Funded by the German Federal Ministry of Education and Research.
Funding reference: 031B1031

Flexible Products

Flexible materials can be found in many applications. The decisive reasons for their practical use are often the freedom in shaping, the low thickness, associated with the low weight, or a high mechanical robustness of the materials.

The core activity of the business area is the modification of the surface properties of flexible materials. Fraunhofer FEP has a wide range of processes at its disposal for this purpose. Roll-to-roll coating has a prominent position in this regard. This is a highly efficient manufacturing principle that is essential for the low-cost production of many products. Examples of this can be found in various industries. Representative examples are food packaging and flexible organic electronics.

Depending on the application and basic technology, the coatings are applied either in vacuum or under atmospheric pressure. They aim to adapt precisely the surface properties to the user scenario. The conductivity of the surface, the optical properties, the diffusion properties for gases and various other properties can be subject of modification. Often, the right combination of several features is also important.

Fraunhofer FEP is uniquely positioned to accompany development projects with industrial customers. This may include the conception, feasibility studies or pilot production and process transfer to the project partner. For this purpose, a highly motivated team of employees is available, as well as extensive equipment for coating and characterization of the materials.

Roll-to-roll fabrication of flexible OLED area lighting on ultrathin glass

Contact: Dr. Matthias Fahland | Phone +49 351 2586-135 | matthias.fahland@fep.fraunhofer.de

The goal in the LAOLA project was to use ultra-thin glass as a substrate and as an encapsulation material. Coating, laminating, and separating the material into individual units was optimized in demonstrators for surgical facility lighting.

Prototype of surgical facility lighting system employing OLEDs on ultra-thin glass and LEDs
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Roll-to-roll (R2R) coating of organic electronics offers potential for novel products - especially when combined with other coating technologies.

An impressive example of this was provided by the LAOLA project (Large-area OLED Lighting Applications on Thin Flexible Substrates) that was completed in 2021. The goal was to develop glare-free, homogeneous light sources. This was accomplished by employing large-area organic light-emitting diodes (OLED) in combination with transparent, electrically conductive oxides (TCO). The focus of the technological development was on the use of flexible ultra-thin glass. This material provided advantages compared to commonly used plastics thanks to its excellent barrier properties.

During the project, an existing roll-to-roll vacuum coating system from FHR Anlagenbau GmbH located at Fraunhofer FEP was converted in such a way that handling, coating, and lamination of ultra-thin glass (50 µm and 100 µm thickness) could be realized under vacuum. The adaptation of the metal evaporation unit for co-evaporation of metals was carried out by CREAVAC-Creative Vakuumbeschichtung GmbH, one of the project partners.

Mixed layers of Ca:Ag and Mg:Ag for the anode and cathode with different concentrations and layer thicknesses were deposited and optimized. A considerable portion of the technologies were worked on as part of an internationalization project with Japanese institutions (Yamagata University, Nippon Electric Glass). Sputtering of TCO layers and screen printing of patterns are processes that present high stability requirements in substrate materials. The annealing of the printing pastes at temperatures of about 140°C and the subsequent cleaning to remove residual paste from the screen-printed etching process were all carried out in an R2R process and could be optimized in the project. In addition to the technological developments, suitable applications were also reviewed as part of the LAOLA project.

Wolfram Designers and Engineers, one of the project partners, designed a new type of operating table lighting system combining highly efficient LED spotlights in the hub of the operating light fixture with glare-free area OLEDs (size: 200 × 80 mm²), installed in 6 hinged panels.

Supported by:

Federal Ministry of Education and Research

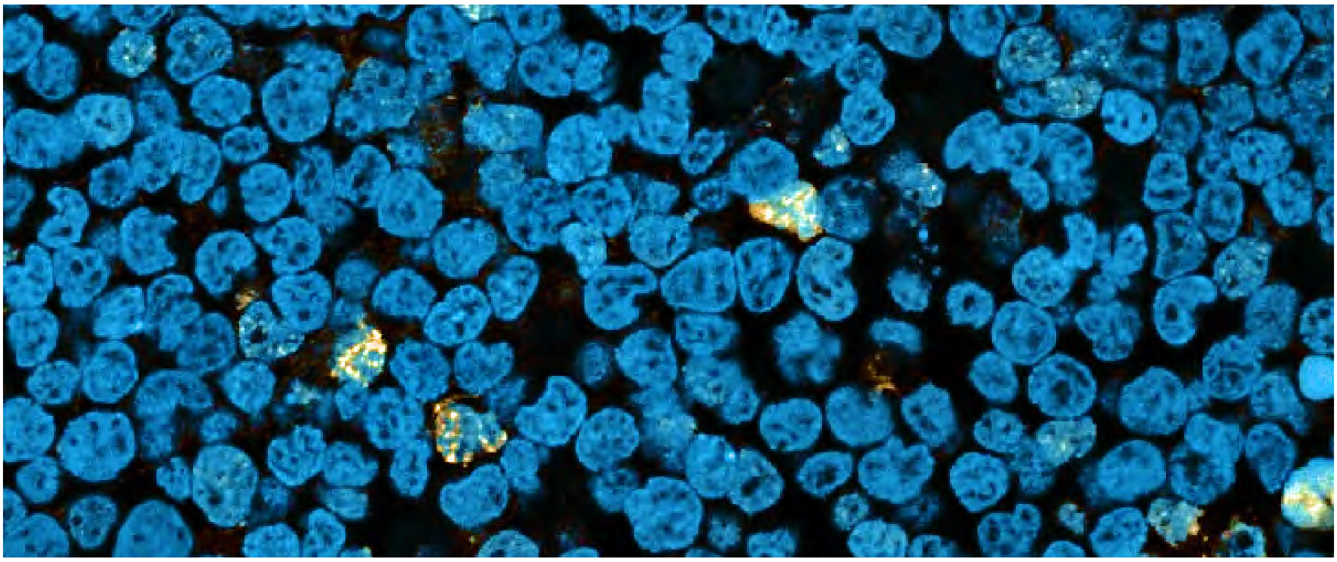
Funded by the German Federal Ministry of Education and Research.
Funding reference: 03INT509AF

Medical and Biotechnological Applications

Due to the ongoing pandemic situation, research activities continued to focus on hygiene and vaccine production. As part of two Fraunhofer in-house anti-corona cluster projects, novel antiviral coatings including comprehensive biological analytics were developed in one project, and innovative disinfection systems that were verified with regard to their disinfection effectiveness were realized in another.

Low-energy non-thermal electron-beam processes can be integrated into diverse areas of the life sciences as an alternative and gentle technology. Accelerated electrons are not only an effective tool for selective surface modification and sterilization, but also serve as a pioneering replacement for a chemical-free vaccine production. The collaborating teams from the Fraunhofer institutes IZI, IPA, and FEP were jointly awarded the 2021 Fraunhofer Prize for their more efficient and environmentally friendly vaccine manufacturing process. The first user-friendly prototype for pharmaceutical production is currently being designed in conjunction with an industrial partner.

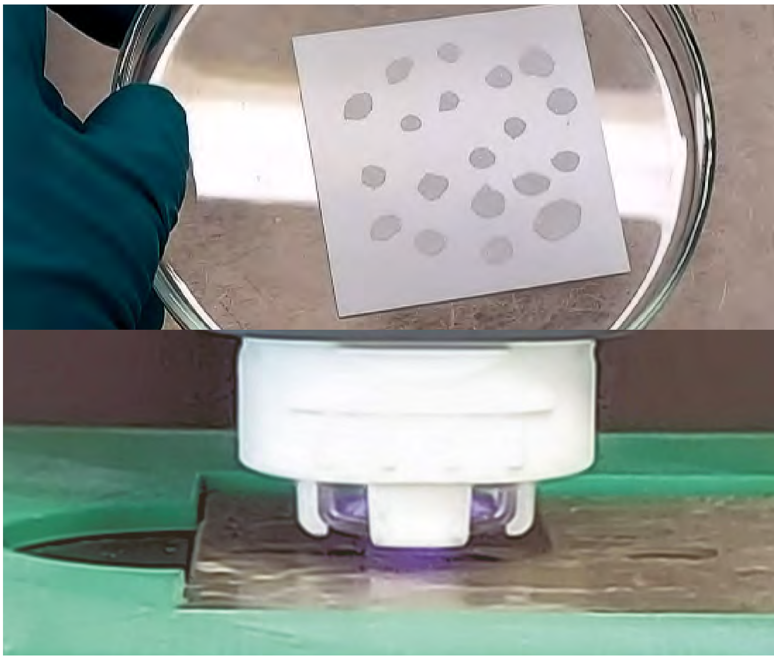
Further development of tailored low-energy electron-beam equipment for treating aqueous systems is progressing with the miniaturization of electron-beam sources that can be employed for various biotechnological processes in bioreactors. New research activities are involved with the positive effects of accelerated electrons on microorganisms and cells, which can provide important support for processes such as bioleaching.



Development and evaluation of autonomous cleaning and disinfection technologies

Contact: M. Sc. Linda Steinhäußer | Phone +49 351 2586-357 | linda.steinhaeusser@fep.fraunhofer.de

In the MobDi project, robotic solutions were developed for the autonomous, efficient, and gentle cleaning and disinfection of surfaces in buildings and public transportation, as well as for automated and hygienic transportation of goods.



Establishment of application relevant contamination scenarios by pre-contaminating plastic surfaces with microorganisms and subsequently disinfecting them using atmospheric pressure plasma © Fraunhofer FEP

One key in the fight against pathogens and the continuing pandemic is to minimize the risk of infection. Around 80% of infections are transmitted through contact with hands and objects. For disinfecting surfaces, the correct technique and execution are crucial factors. Cleaning robots can be particularly useful in areas with high turnover and frequently touched surfaces.

This challenge was addressed by the Fraunhofer-Gesellschaft's in-house anti-corona cluster project »Mobile Disinfection« (MobDi) in which twelve participating Fraunhofer institutes developed and evaluated new hardware and software solutions for deploying mobile service robots. The Fraunhofer FEP acted as the interface between biology and technology and was responsible for evaluating the degree of microbiological contamination of specific surfaces.

The goal in developing the robot's disinfection tools was to determine the suitable operational parameters for killing pathogens quickly and cost-effectively, as well as being gentle on materials. An LED emitting UV and a plasma jet were developed, and a dry steam vacuum cleaner unit was modified for use by the robot. Disinfection levels up to 99.999% (5 log levels) could be demonstrated with these established disinfection tools. Application of both UV and plasma for disinfection produced a synergetic effect. Targeted and situation-specific cleaning and disinfection is feasible thanks to smart perception functions by the robot. With the aid of a multimodal 3D sensor, objects and their materials can be autonomously recognized by the robot. Based on the data generated in the project, the robot can then select the most suitable disinfection tool for cleaning the object. All the necessary information is brought together in a multilayer model of the robot's environment so that it can plan its cleaning sequences autonomously. Additional sensors also enable the robot to maneuver safely in the presence of people, so that it can be used in high-traffic areas as well. Hygienic design of the robot and its self-cleaning and decontamination routines prevent the robot itself from becoming a contamination risk.

Funded within the framework of the Internal Programs of the Fraunhofer-Gesellschaft. Funding reference: Anti-Corona 840264.

Microdisplays and Sensors

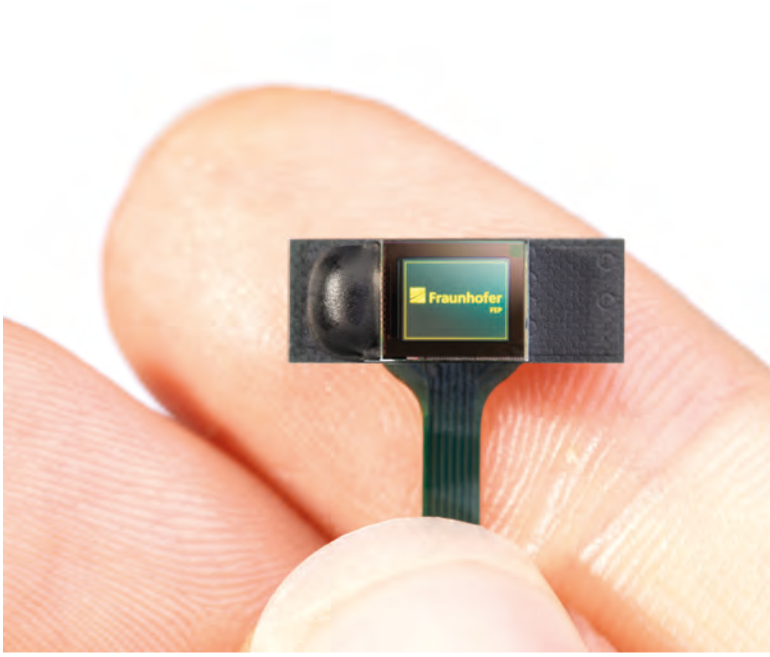
The business unit „Microdisplays and Sensors" is offering R&D addressing component/device design and manufacturing technologies based on organic and inorganic semiconductors, e. g., organic light emitting diodes (OLED), photodetectors, µLED, that are integrated into silicon CMOS and MEMS backplanes. Therefore we focus on the supply chain from CMOS-IC design (backplane), wafer supply with commercial Silicon Foundries, up to frontplane definition and processing (e. g., emitters, absorbers), providing prototypes and pilot-fabrication. So far most important technology is OLED-on-Silicon, providing the basis for OLED "microdisplays". For "sensor" applications it is often combined with additional sensing layers (e.g., material- and ion-sensitive dyes), to enable detection of e. g., pH, oxygen or carbon dioxide concentrations in gases or liquids.

Though we focus on components and their manufacturing technologies, knowledge on system integration (e. g., smart glasses) and applications (e. g., motorcycle helmet head-up display) remains vital for provident development of innovative features (e. g., luminance, color space, lifetime, resolution, response time, spectral sensitivity). This experience enables tight collaboration with application, system integration and supply chain partners.

Multicolor OLED microdisplay with minimum power consumption

Contact: Dr. Uwe Vogel | Phone +49 351 2586-160 | uwe.vogel@fep.fraunhofer.de

Fraunhofer FEP has succeeded in realizing a multi-color ultra-low power (ULP) OLED micro-display that consumes the lowest power of all available microdisplays, enabling an extended range of applications compared to our previous monochrome ULP platform.



Ultra-low power OLED microdisplay
© Fraunhofer FEP, Photographer: Claudia Jacquemin

Wearables have become widespread nowadays: Used as fitness wristbands, they measure body parameters during sports. In industry, cumbersome manuals become replaced by smart glasses displaying information directly. While cycling navigation is provided by a tiny near-to-eye system guiding the user where to ride. Obviously, those systems have to consume very little power, because one doesn't want to get off the bike for recharging.

Therefore, the ultra-low power micro-display platform for wearables has been designed for ultra-low power (ULP) consumption, based on "OLED-on-silicon" technology. Such ULP OLED microdisplays were previously available in monochrome only, sufficient for simple information display so far. To expand the range of applications, a multi-color OLED micro-display has now been researched within the »BACKPLANE« project, which can display the color space of green, red and their mixed colors, and still requires less power than all other microdisplays. That enables fast and vivid visual signals by red and green colors, for example as a warning display in firefighters´ helmets or for professional divers. For example, a welder can always follow the thermal image at a weld seam, or a nurse in protective clothing with integrated sensors can immediately see if the patient has higher temperature.

Visualizing heat differences was not possible with the ULP OLED microdisplays offered previously. Thus, FEP has created an innovative display concept that allows multi-color and higher data rates by reducing the pixel size by half, whereas the tiny form factor enables extremely compact systems. Scientists are now looking forward to discuss its opportunities with industrial customers, for adapting it to their requirements.

In collaboration with GLOBALFOUNDRIES Dresden, Module One LLC & Co. KG and digades GmbH, Fraunhofer FEP is currently researching a solution for low-power and high-resolution OLED microdisplays and high-resolution cameras. The aim is an ultra-low power microdisplay backplane architecture in a deep-submicron CMOS process, thus significantly reducing the previously predominant area required by memory components for static RAM (SRAM).

European Union
Europe funds Saxony.
EFRE
European Regional Development Fund

Funded by the European Union and the Free State of Saxony.
Funding reference: 100392259

STAATSMINISTERIUM FÜR WIRTSCHAFT ARBEIT UND VERKEHR
Freistaat SACHSEN

Precision Coating

The focus of our technology development is on reactive pulse magnetron sputtering (PMS) for the deposition of compound layers. Precision is required here to achieve excellent homogeneity of layer thicknesses (<±0.5 %), even over larger substrates. But it is also necessary to reproducibly control mechanical, optical, electronic and other layer properties. The in-house development of key components such as magnetrons, pulsed energy supplies, gas control and process control provides engineering and technology from a single source.

Application examples include:

- Optical interference coatings, also laterally or vertically graded
- Piezoelectric and ferroelectric coatings for microsystems (MEMS), high-frequency filters (BAW), ultrasound microscopy, non-volatile memories, as well as micro-energy generation
- Electrical insulation coatings for sensors (including integrated circuits and modules), electronics and photovoltaics
- Passivation, barrier, and protective layers for sensors and electronics
- TiO_2 layers with photocatalytic, antimicrobial and super-hydrophilic properties
- Epitaxially grown AlN and GaN layers for applications in power and RF electronics as well as for operating room lighting with LED and OLED on ultra-thin glass

Inline magnetron sputtering for optical filters on 2D and 3D substrates such as for holographic head-up displays

Contact: Dr. Daniel Glöß | Phone +49 351 2586-374 | daniel.gloess@fep.fraunhofer.de

Optical filters were deposited on a wide variety of 2D and 3D substrates using inline magnetron sputtering in the PreSensLine precision coating equipment. An example of a large-area filter is a selective reflection filter for a holographic head-up display on part of a car windshield.

New optical applications, such as head-up displays in cars as well as new holography-based displays, place high demands on coating technology and equipment. The resulting need for development was investigated in the 3D-FF project on the PreSensLine precision coating system, both in terms of the optical functionality of more complex layer stacks and in terms of the coating technology for large and curved substrates. The optical functionality as well as the high homogeneity requirements were able to be demonstrated during the project.

Excellent coating properties for optical filters can be achieved using inline magnetron sputtering. These include low absorption, low scattering, low coating roughness, low mechanical layer stress, and low particle density [1]. The process is also suitable for deposition of coatings on high-performance laser mirrors. Various inline coating systems are available at the Fraunhofer FEP that are suitable for fabricating optical filters, such as ILA 750 (substrate size up to 450 × 400 mm), ILA 900 (1200 × 600 mm) and PreSensLine (780 × 680 mm).

The PreSensLine precision coating equipment gives Fraunhofer FEP the capability to transfer the processes of typical throughput-limited optical coating systems operating in batch mode to dynamic coating and thus to large-area substrates. In-situ adjustable trim shields and a highly dynamic substrate drive allow selective lateral grading of layers on flat substrates, or homogeneous coating on curved substrates.

The system has already been used to deposit a wide variety of optical filters on large substrates. These included flat glass substrates up to 450 mm × 450 mm with thicknesses of 2 – 19 mm and curved substrates including panes of curved glass and automobile windows. In most cases, the optical filters were needed as anti-reflection systems or wavelength-selective mirrors for laser applications.

Photo of the demonstrator for a holographic head-up display with coated windshield (maximum edge length 780 mm × 680 mm), set up at SeeReal Technologies GmbH

The filter fabricated on the windshield as part of the 3D-FF project – the largest substrate to date – measured 780 mm × 680 mm. It was a selective reflector for a holographic head-up display being developed by SeeReal Technologies GmbH, a project partner. This optical filter reflects a large part of the light emitted by the projection system without greatly affecting the view through the windshield. A corresponding demonstrator was set up at SeeReal Technologies with the windshield coated by Fraunhofer FEP.

European Union
Europe funds Saxony.
EFRE
European Regional Development Fund
Funded by the European Union and the Free State of Saxony. Funding reference: 100354086

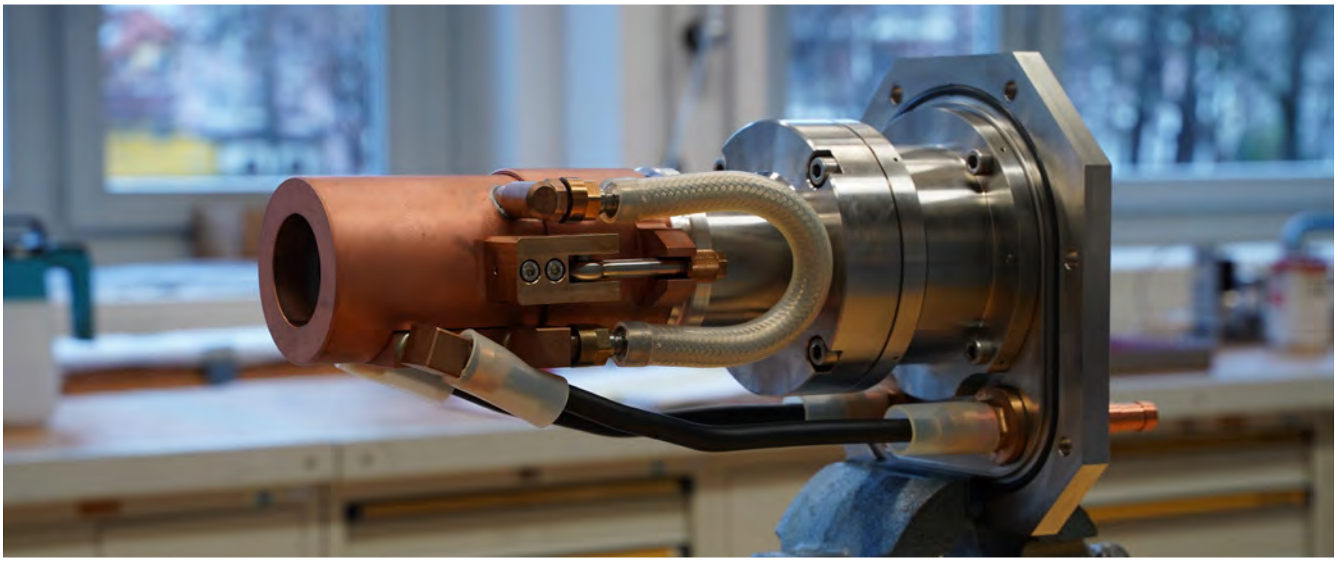
[1] Daniel Gloess et al., "Freeform and Laser Optical Coatings by Inline Magnetron Sputtering", Proceedings of Optical Interference Coatings Conference OIC 2019

Systems

Technology and hardware development go hand-in-hand at the Fraunhofer FEP. The electron beam and plasma components required within the institute are often not available on the market and are specially developed or modified to meet the requirements for new applications. The development and realization of this hardware takes place within our Systems division. Equipped with mechanical and electronic development facilities as well as workshop fort the realization of prototypes, we are able fully cover the whole process for an idea from conception and development to its realization.

In-house development of our hardware allows close collaboration with process engineers during the entire development process. This fastens the iterative process and allows us to quickly reach our goal: technology transfer to industry. Support activities during process development promote continuous development of the Fraunhofer FEP's key components.

The development portfolio of our key technological components includes plasma and electron beam sources suited to a wide range of applications. These components together with the technologies developed at the Fraunhofer FEP have already proven their suitability for industry.



Double Ring Magnetron 400 (DRM 400)

Contact: Dr. Michiel Top | Phone +49 351 2586-355 | michiel.top@fep.fraunhofer.de

The DRM 400 double ring magnetron is one of our key components. Triggered by increased requirements in power electronics applications, we completed the first DRM 400 UHV prototype in 2021 for use under ultra-high vacuum and put it into operation at our facilities.

General view of the double ring magnetron – DRM 400 seen from the coating side
© Fraunhofer FEP

A successful example of our key components is the DRM 400 double ring magnetron. The DRM 400 was developed over several years at the Fraunhofer FEP for precision deposition of optical and electrical coatings for applications in the fields of sensors, electronics, and interference optics. Continuous development of the target, the vapor delivery system, and the magnet system resulted in a high-performance tool for the coating industry.

Triggered by increased purity requirements for deposition layers originating from applications in the area of power electronics, further development of the magnetron for ultra-high vacuum use began in 2019. A key challenge here was the large number of vacuum feedthroughs for gas supply, power, in-line sensors, and moving parts. After two years of development and prototyping, the first ultra-high vacuum DRM 400 (UHV) prototype was put into operation at our institute. This development has improved the baseline pressure by an order of magnitude compared to the standard DRM 400.

In addition, a high-performance cooling system for the target was integrated into the magnetron that enables the surface temperature of the targets to be held at room temperature in a sputter-coating environment characterized by high heat load (substrate temperatures up to 1000°C) and at sputtering powers of up to 6 kW. This enables a gallium target to remain in solid state during the sputtering process, despite its melting point of only 27°C.

The primary application of the new magnetron is epitaxial growth of aluminum-nitride and gallium-nitride layers on silicon wafers in order to be able to manufacture highly efficient electronic power components more cost-effectively. Further development is also expected to open up other application areas in which residual gas contamination of the layer plays a major role.

Funded by the Horizon 2020 Research and Innovation Programme of the European Union.
Funding reference: 783174

Supported by:

Federal Ministry of Education and Research

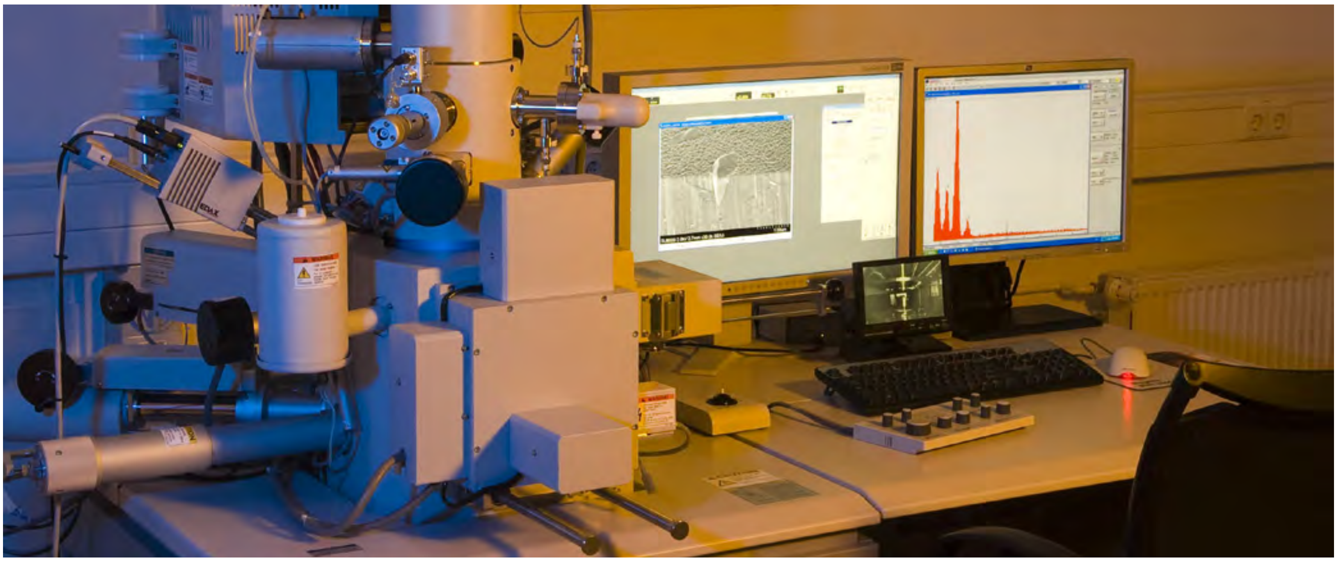
Funded by the German Federal Ministry of Education and Research.
Funding references: 16ES1089K and 16ESE0058S

Materials Analysis

The Materials Analysis department has a variety of methods available for characterizing the structure and properties of thin films. The analytical methods and the extensive experience of our staff are applied in research projects and are also offered to our customers as services.

A high-resolution field-emission scanning electron microscope (FE-SEM) and an X-ray diffractometer (XRD) are available for characterizing of structure and microstructure of thin films. Polished cross-sections of multilayer systems can be prepared using an ion beam preparation technique, facilitating high-resolution FE-SEM examination in both material contrast mode and crystal-orientation contrast mode. Chemical composition is analyzed by energy-dispersive spectrometry of X-rays (EDS) and by glow-discharge optical emission spectrometry (GD-OES).

Many other measurement methods are available at the Fraunhofer FEP for determining the optical, mechanical, and electrical properties of thin layers. These include UV, VIS, and NIR spectrometry, spectroscopic ellipsometry, and nanoindentation. We have further extensive experience in the field of permeation barrier measurements for water vapor and oxygen through coated polymer films.



High-resolution studies of the piezoelectric properties of (Al,Sc)N layers

Contact: Dr. Olaf Zywitzki | Phone +49 351 2586-180 | olaf.zywitzki@fep.fraunhofer.de

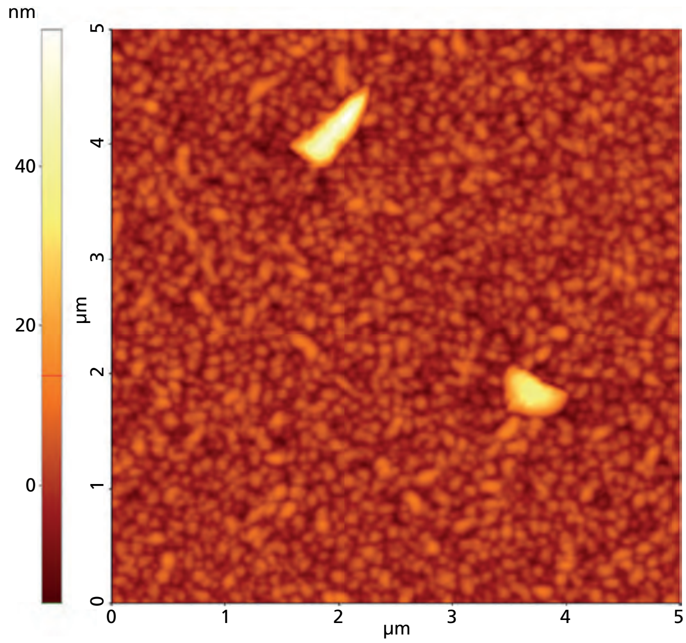
(Al,Sc)N layers are used in mobile communications and sensor technology. Piezo force microscopy can be used to determine the piezoelectric properties of the layers with very high lateral resolution, facilitating further optimizations.

Piezoelectric (Al,Sc)N layers are used in radio-frequency filters for surface acoustic wave (SAW) devices in mobile communications technology, for example. Other applications include piezoelectric sensors for use at high temperatures in automobiles and turbines. Incorporation of scandium into the hexagonal wurtzite structure of AlN increases the piezoelectric charge constant in the direction of the polar c-axis by up to a factor of four and simultaneously improves the electromechanical coupling, resulting in more efficient conversion of mechanical energy into electrical energy.

Determining the piezoelectric properties of layers deposited by magnetron sputtering is mainly carried out by measurements using a Berlincourt piezometer or alternatively using dual-beam interferometry. In both cases, an integral measurement is made via the electrodes used, which are approximately one to ten millimeters in diameter.

In contrast, piezo force microscopy (PFM) that is used in current studies enables lateral measurements of the piezoelectric properties to be made at much higher resolution – down to the nanometer range. To do this, an AFM examination of the layers is performed in contact mode. By additionally applying an alternating voltage of 10 V to the AFM tip, the inverse piezoelectric effect causes a local deflection of the surface, which is registered by a four-quadrant detector and can be analyzed by means of a lock-in amplifier.

Local differences in piezoelectric properties can be investigated at high resolution with this method. Thus, individual crystallites with deviating crystallographic orientation can be detected in both the topographic AFM image and by the lower amplitude of the piezoelectric signal. The local polarity of the wurtzite structure can also be simultaneously resolved from the phase of the piezoelectric signal measured. Previous studies have shown that the polarity of the structure can be influenced by parameters of the layer deposition process, from N-polar through bipolar to Al-polar. The results of the high-resolution PFM studies are an important contribution to improving piezoelectric properties of (Al,Sc)N coatings.



AFM image of a (Al,Sc)N layer with crystallites exhibiting deviating crystallographic orientations (topography)
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Appendix

The Fraunhofer-Gesellschaft

The Fraunhofer-Gesellschaft based in Germany is the world's leading applied research organization. Prioritizing key future-relevant technologies and commercializing its findings in business and industry, it plays a major role in the innovation process. It is a trailblazer and trendsetter in innovative developments and research excellence. The Fraunhofer-Gesellschaft supports research and industry with inspiring ideas and sustainable scientific and technological solutions and is helping shape our society and our future.

The Fraunhofer-Gesellschaft's interdisciplinary research teams turn original ideas into innovations together with contracting industry and public sector partners, coordinate and complete essential key research policy projects and strengthen the German and European economy with ethical value creation. International collaborative partnerships with outstanding research partners and businesses all over the world provide for direct dialogue with the most prominent scientific communities and most dominant economic regions.

Founded in 1949, the Fraunhofer-Gesellschaft currently operates 76 institutes and research units throughout Germany. Over 30,000 employees, predominantly scientists and engineers, work with an annual research budget of €2.9 billion. Fraunhofer generates €2.5 billion of this from contract research. Industry contracts and publicly funded research projects account for around two thirds of that. The federal and state governments contribute around another third as base funding, enabling institutes to develop solutions now to problems that will become crucial to industry and society in the near future.

The impact of applied research goes far beyond its direct benefits to clients: Fraunhofer institutes enhance businesses' performance, improve social acceptance of advanced technology and educate and train the urgently needed next generation of research scientists and engineers.

Highly motivated employees up on cutting-edge research constitute the most important success factor for us as a research organization. Fraunhofer consequently provides opportunities for independent, creative and goal-driven work and thus for professional and personal development, qualifying individuals for challenging positions at our institutes, at higher education institutions, in industry and in society. Practical training and early contacts with clients open outstanding opportunities for students to find jobs and experience growth in business and industry.

The prestigious nonprofit Fraunhofer-Gesellschaft's namesake is Munich scholar Joseph von Fraunhofer (1787–1826). He enjoyed equal success as a researcher, inventor and entrepreneur.

Customers and contractual partners are:

- Industry
- Service sector
- Public administration

Key figures at a glance

- 76 institutes and research units
- 30,000 staff
- 2.9 billion euros annual research budget totaling
- About 70 percent of the Fraunhofer-Gesellschaft's contract research revenue is derived from contracts with industry and from publicly financed research projects
- International cooperation through affiliated research centers and worldwide representative offices

www.fraunhofer.de

Fraunhofer Group for Light & Surfaces

The Fraunhofer Group for Light & Surfaces brings together the Fraunhofer-Gesellschaft's scientific and technical expertise in the areas of laser, optical, measurement and surface technology.

Members are the Fraunhofer institutes for

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- Telecommunications, Heinrich Hertz Institute HHI
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- Optronics, System Technologies and Image Exploitation IOSB
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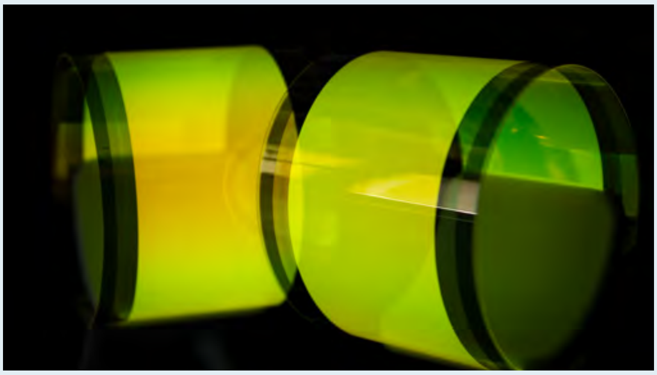
With a total of approximately 1900 employees, the Fraunhofer Institutes in the Group work together to solve complex, application-oriented customer inquiries at the cutting edge of science and technology.

But the Fraunhofer Institutes are not only partners in innovation. They also work to produce new generations of scientific and technical experts. In cooperation with the local universities, the young scientists at the Fraunhofer Institutes bring together academic research and industry.

Since October 2019, Prof. Karsten Buse (Fraunhofer IPM) has been the Chair of the Group and Dr. Heinrich Stülpnagel has been head of central office.



Central Office

Fraunhofer Institute for Physical Measurement Techniques IPM

Georges-Köhler-Allee 301
79110 Freiburg

Phone +49 761 8857-269
Fax +49 761 8857-224

www.light-and-surfaces.fraunhofer.de

Memberships

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- International Electrotechnical Commission IEC, TC 110 Electronic display devices, WG 12 Eyewear display
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- International Irradiation Association
  www.iiaglobal.com
- Kompetenznetz Industrielle Plasma-Oberflächentechnik INPLAS e. V.
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- LRT Sachsen / Thüringen e. V.
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- Netzwerk »CleanHand«
  www.cleanhand.de
- OLED Lichtforum
  www.oledlichtforum.de
- Organic Electronics Saxony e. V.
  www.oes-net.de
- Photonics 21
  www.photonics21.org
- Plasma Germany
  www.plasma-germany.org
- RadTech Europe – European Association for the Promotion of UV and EB curing
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- VDMA Arbeitsgemeinschaft Organic Electronics Association (OE-A)
  www.oe-a.org
- Verband Deutsches Reisemanagement e. V. (VDR)
  www.vdr-service.de/der-verband/der-vdr
- Virtual Institute of Nano Films
  www.vinf.eu
- ZIM Netzwerk „Biokompatible IoT-Lösungen für Biotechnologie und Medizintechnik“
  www.biomed-iot.de

Theses

Diploma Theses

Author	Title	University
M. Wang	Electron treatment of polymer films	TU Dresden, Fakultät Maschinenwesen, Institut für Werkstoffwissenschaften,
D. Herrmann	In-Line Poliersystem für Präzisionswalzen	TU Dresden, Fakultät Maschinenwersen, Institut für Fertigungstechnik
J. Feng	Verbesserungskonstruktion einer Gasfluss-Sputterquelle, (GFS)-Hohlkathode und Gasphasen-Aggregationskammer	Hochschule für Technik und Wirtschaft Dresden, Fakultät Maschinenbau, Studiengang Konstruktion

Master Theses

Author	Title	University
M. Rhode	Abscheiden von Plasmapolymerschichten mittels eines PECVD-Verfahrens mit kapazitiv gekoppelter Hochfrequenz-entladung unter Nutzung von TEOS und verschiedenen Precursormischungen	Hochschule Osnabrück, Fakultät Ingenieurwissen-schaften und Informatik, Studiengang Angewandte Werkstoffwissenschaften
M. Pfeilschifter	Markt-und Trendanalyse in der industriellen Teilereinigung	TH Bingen, Wirtschaftsingenieurwesen
P. Gerö	Integration neuer Anforderungen in ein bestehendes Managementsystem am Beispiel der Informationssicherheit im Projektgeschäft am Fraunhofer-Institut FEP Dresden	Hochschule Zittau/Görlitz, Studiengang Integrierte Managementsysteme
H. Alhatemi	Aufbau und Test eines Messplatzes zur Bestimmung der Durchstoßfestigkeit	TU Chemnitz, Fakultät Maschinenwesen, Studiengang Maschinenbau
I.Stier	Verarbeitbarkeit von biobasierten Folien in Standardmaschinen	HTWK Leipzig, Fakultät Informatik und Medien, Studiengang Druck- und Verpackungstechnik
L.F. Hernandez Bonilla	Organic electronics on biodegradable substrates	TU Dresden, Fakultät für organische Halbleiter, Institut für angewandte Physik,
S. Nagarajan	Dosismessung bei Elektronenbehandlungen	Ernst-Abbe-Hochschule Jena
N. Stöckl	Analyse der Effekte von Beschichtungstemperatur und thermo-mechanischen Belastungen auf die Schichtspannung von beschichteten Polymerfolien	TU Dresden, Fakultät Physik, Studiengang Physik

Publications

Authors	Title	Place of publication
E. von Hauff	2D or not 2D: Eliminating interfacial losses in perovskite solar cells	Chem, Vol. 7, Issue 7, 2021, p. 1694 - 1696
A. Jannasch, J. Rix, C. Welzel, G. Schackert, M. Kirsch, U. König, E. Koch, K. Matschke, S.-M. Tugtekin, C. Dittfeld, R. Galli	Brillouin confocal microscopy to determine biomechanical properties of SULEEI-treated bovine pericardium for application in cardiac surgery	Clinical Hemorheology and Microcirculation, Vol. 79, Nr. 1, 2021, p. 179-192
E. Hieckmann, K. Kammerlander, L. Köhler, L. Neumann, S. Saager, N. Albanis, T. Hutsch, F. Seifert, E. Brunner	Detection and Localization of Eu on Biosilica by Analytical Scanning Electron Microscopy	Microscopy and Microdisplays, Vol. 27, Issue 6, 2021, p. 1328 - 1337
F.-H. Rögner, U. Vohrer	Die Erweiterung des Sinner´schen Kreises	Journal für Oberflächentechnik JOT, Sonderheft 07, 2021, S. 10 - 12
J. Fichtner, Y. Kowalik, T. Kowalik, J. Fahlteich, B. Mayer	Electron beam cured acrylates as potential planarization layers	Materials Chemistry and Physics, Vol. 274, 2021, Artikel 125161
C. May	Flexible OLED lighting and signage for automotive application	Proceedings of 28th International Workshop on Active-Matrix Flatpanel Displays and Devices (AM-FPD), p. 42 - 45
B. Zimmermann, G. Mattausch, F. Fietzke, J.-P. Heinß, B. Scheffel, M. Top, C. Metzner	Gas discharge electron sources - powerful tools for thin film technologies	Proceedings of 64th Annual SVC Technical Conference, virtual, 01. - 06. May 2021, p. 1 - 7
C. Dittfeld, U. König, C. Welzel, A. Jannasch, K. Matschke, C. Sperling, S.- M. Tugtekin, M. Maitz	Haemocompatibility testing allows selective adaption of GA-free SULEEI-preparation strategy for bovine pericardium	European Heart Journal, Vol. 42, Issue 1, 2021, Artikel 724.3336
C. Welzel, C. Dittfeld, A. Jannasch, U. König, C. Sperling, M. F. Maitz, K. Matschke, S.-M. Tugtekin	Hemocompatibility Assays Offer a New Option for Evaluation of Decellularized Bovine Pericardium for Application in Cardiac Surgery	The Thoracic Cardiovascular Surgeon, Vol. 1, 2021, p. 69
M. Thoma, J. Fertey, G. Gotzmann, S. Bailer	Impfstoffe günstig herstellen - Neues Verfahren zur Inaktivierung von Erregern in Flüssigkeiten	TechnoPharm, Vol. 11, Nr. 4, 2021, p. 180 - 183
D. Becker, M. Bott, F.-H. Rögner, G. Mattausch, U. König, M. Thoma, B. Standfest, S. Ulbert, J. Fertey, H. Gehringer, P. Kitschmann	Inaktivierung von Pathogenen durch niederenergetische Elektronenstrahlung	pharmind, Vol. 83, Nr. 11, 2021, Seite 1508 - 1532
G. Colombi, T. De Krom, D. Chaykina, S. Cornelius, S. W. H. Eijt, B. Dam	Influence of Cation (RE = Sc, Y, Gd) and O/H Anion Ratio on the Photochromic Properties of REOxH3-2x thin Films	ACS Photonics, Vol. 8, Issue 3, 2021, p. 709 - 715
G. Gotzman, U. König	Kampf den Keimen: Antibakterielle Beschichtungen, Oberflächenfunktionalisierung und Sterilisation durch Elektronen	mo, Vol. 75, Nr. 6, 2021, Seite 14 - 15
L. Walcher, A.-K. Kistenmacher, C. Sommer, S. Böhlen, C. Ziemann, S. Dehmel, A. Braun, U. Sandy Tretbar, S. Kloess, A. Schambach, M. A. Morgan, D. Löffler, C. Kämpf, C. Blumert, K. Reiche, J. Beckmann, U. König, B. Standfest, M. Thoma, G. R. Makert, S. Ulbert, U. Kossatz-Böhlert, U. Koehl, A. Dünkel, S. Fricke	Low-energy electron irradiation as a potent alternative to gamma irradiation for the inactivation of (CAR-)NK-92 cells ATMP manufacturing	Frontiers in Immunology, Section Cancer Immunity and Immunotherapy, Vol. 12, 2021, Artikel 684052

Authors	Title	Place of publication
F.H. Rögner, M. Pfeilschifter	Markt- u. Trendanalyse in der industriellen Teilereinigung 2020	ISBN: 978-3-00-069601-5, Geschäftsbereich: Reinigung bei Fraunhofer
M. Prosa, E. Benvenuti, D. Kallweit, P. Pellacani, M. Törker, M. Bolognesi, L. Lopez-Sanchez, V. Ragona, F. Marabelli, S. Toffanin	"Organic Light-Emitting Transistors in a Smart-Integrated System for Plasmonic-Based Sensing"	Advanced Functionals Materials, 2021, Artikel 2104927
S. Lenk, B. Richter, P. Wartenberg, U. Vogel	Organic Microdisplays for Visual Feedback	Proceedings of OSA Advanced Photonics Congress, 26.-29. Juli, 2021, Montreal, Canada, online, 2 pages
Y. Sun, A. G. Chmielewski, A. Pawelec, G. Mattausch, T. Torims	Organic pollutant removal from marine diesel engine off-gases under electron beam and hybrid electron beam and wet scrubbing process	NUKLEONIKA, Vol. 66, Nr. 4, 2021, p. 193 - 199
A. Pawelec, A. G. Chmielewski, Y. Sun, S. Bułka, T. Torims, G. Pikurs, G. Mattausch	Plasma technology to remove NOx from off-gases	NUKLEONIKA, Vol. 66, Nr. 4, 2021, p. 227 - 231
B. Scheffel, O. Zywitzki, T. Preußner, T. Kopte	Plasma-assisted deposition of ITO thin films by sublimation using an anodic vacuum arc discharge	Thin Solid Films, Vol.731, 2021, Artikel 138731
M. Schwartzkopf, S. J. Wöhnert, V. Waclawek, N. Carstens, A. Rothkirch, J. Rubeck, M. Gensch, J. Drewes, O. Polonskyi, T. Strunskus, A. M. Hinz, S. J. Schaper, V. Körstgens, P. Müller-Buschbaum, F. Faupel, S. V. Roth	Real-time insight into nanostructure evolution during the rapid formation of ultra-thin gold layers on polymers	Nanoscale Horizons, Vol. 6, Issue 2, 2021, p. 132 - 138
S. Schaper, F. Löhrer, S. Xia, C. Geiger, M. Schwartzkopf, P. Pandit, J. Rubeck, B. Fricke, S. Frenzke, A. M. Hinz, N. Carstens, O. Polonsky, T. Strunskus, F. Faupel, S. Roth, P. Müller-Buschbaum	Revealing the growth of copper on polystyrene: Block -poly(ethylene oxide) diblock copolymer thin films with in situ GISAXS	Nanoscale, Vol. 13, Issue 23, 2021, p. 10555 - 10565
D. Wang, J. Hauptmann, C. May, Y. J. Hofstetter, Y. Vaynzof, T. Müller	Roll-to-roll Fabrication of Highly Transparent Ca:Ag Top-Electrode for Flexible Large-Area OLED Lighting Application	Flexible and Printed Electronics, Vol. 6, Nr. 3, 2021, Artikel 035001
E. Altinsoy, T. Hulin, U. Vogel, T. Bobbe, R. Dachselt, K. Klamka, J. Krzywinski, S. Lenk, L.-M. Lüneburg, S. Merchel, A. Nocke, H. Singh, A. Schwendicke, H. Winger	Sensors and actuators	Tactile Internet with Human-in-the-Loop, Chapter 10, p. 229–254, ISBN: 978-0-12-821343-8
S. Saager, B. Scheffel, T. Modes, O. Zywitzki	Synthesis of Porous Silicon, Nickel and Carbon Layers by Vapor Phase Dealloying	Surface and Coatings Technology, Vol. 427, 2021, Artikel 127812
A. Vilà, S. Moreno, J. Canals, V. Moro, N. Franch, P. Wartenberg, A. Dieguez	Ultra-compact and large field-of-view nano-illumination light microscope based on an array of organic light-emitting diodes	SPIE, Digital Library, Proceedings, Volume 11693, 2021, Photonic Instrumention Engineering VIII

Protective Rights

Patent number	Title	Inventor(s)	Registration	Grant
US 10,907,249 B2	Method for Coating a flexible Substrate provided with a protective Film	M. Fahland, U. Meyer, T. Vogt, S. Günther, J. Fahlteich, N. Prager	07.12.2018	02.02.2021
DE 10 2020 116 043 B3	Verfahren zum Herstellen eines Cellulose enthaltenden Verbundwerkstoffs	W. Nedon, W. Schwarz, F.-H. Rögner, J. Portillo, J. Kubusch	17.06.2020	21.01.2021
CN 106716517 B	Method for Operating a bi-directional Display	B. Richter, P. Wartenberg	17.03.2017	09.03.2021
DE 10 2019 134 558 B3	Vorrichtung und Verfahren zum Beaufschlagen gasförmiger Medien mit beschleunigten Elektronen	G. Mattausch, A. Weidauer, R. Blüthner, J. Kubusch, F.-H. Rögner, V. Kirchhoff, R. Labitzke, B. Zimmermann	16.12.2019	11.03.2021
EP 3 541 441 B1	Method for Preparing a Graft	C. Wetzel, J. Schönfelder, S. Walker, J. Kubusch	08.04.2019	10.03.2021
DE 10 2012 013 726 B4	Vorrichtung zum Kühlen bandförmiger Substrate	J.-P. Heinß, F. Schade, P. Lang, L. Klose, C. Metzner, D. Weiske	11.07.2012	18.03.2021
EP 3 642 861 B1	Apparatus for Generating accelerated Electrons	A. Weidauer, F.-H. Rögner, G. Mattausch, R. Blüthner, I.G. Vicente Gabas, J. Kubusch	28.10.2019	07.04.2021
KR 10-2244994 B1	Method for Depositing a Piezoelectric Film Containing AlN and a Piezoelectric Film Containing AlN	H. Bartzsch, D. Glöß, P. Frach, S. Barth	24.06.2014	21.04.2021
US 10,980,903 B2	Method for Irradiating a Liquid with accelerated Electrons	J. Schönfelder, F.-H. Rögner, J. Portillo Casado, J. Kubusch	07.12.2018	20.04.2021
EP 3 411 513 B1	Method for Depositing a CdTe Layer on a Substrate	H. Morgner, C. Metzner, D. Hirsch, O. Zywitzki, L. Decker, T. Werner, B. Siepchen, B. Späth, K. Verlappan, C. Kraft, C. Drost	27.07.2018	02.06.2021
CN 109641072 B	Inactivation of Pathogens in biological Media	M. Thoma, K. Fischer, J. Portillo	31.08.2017	11.06.2021
CN 109996534 B	Method for Immobilizing Plant active Substances an a non-metallic Substrate	M. Dietze, B. Kemper, J. Kubusch	25.03.2019	13.07.2021
EP 3 590 125 B1	Apparatus for Generating accelerated Electrons	A. Weidauer, F.-H. Rögner, G. Mattausch, R. Blüthner, I.G. Vicente Gabas, J. Kubusch	27.08.2019	04.08.2021
DE 10 2020 116 044 B3	Verfahren zum Restaurieren von einem Papiersubstrat	W. Nedon, W. Schwarz, F.-H. Rögner, J. Portillo, J. Kubusch	17.06.2020	12.08.2021
US 11,081,616 B2	Method for Producing a CdTe Solar Cell	D. Hirsch, O. Zywitzki, T. Modes, T. Werner, T. Kopte, C. Metzner	24.05.2019	03.08.2021
JP 6914280 B2	Method for Coating a flexible Substrate provided with a protective Film	M. Fahland, U. Meyer, T. Vogt, S. Günther, J. Fahlteich, N. Prager	07.01.2019	15.07.2021

Patent number	Title	Inventor(s)	Registration	Grant
EP 3 699 253 B1	Granulate for a thermochemical Heat Accumulator and Method for Producing Granulate for a thermochemical Heat Accumulator	F. Fietzke, J.-P. Heinß, B.-G. Krätzschmar	19.02.2020	15.09.2021
EP 3 635 784 B1	Sensor Component and Method for Producing same	C. Kirchhof	02.12.2019	25.08.2021
DE 10 2020 121 204 B3	Selbstdesinfizierendes antivirales Filtermaterial, dessen Herstellung und Anwendung, sowie Luftfiltereinrichtung mit dem Filtermaterial	M. Hoffmann, H. Böttcher	12.08.2020	21.10.2021
EP 3 469 113 B1	Method for Coating a flexible Substrate provided with a protective Film	M. Fahland, U. Meyer, T. Vogt, S. Günther, J. Fahlteich, N. Prager	07.12.2018	03.11.2021
DE 10 2016 116 762 B4	Verfahren zum Abscheiden mittels einer Magnetronsputtereinrichtung	H. Bartzsch, P. Frach, J. Hildisch	07.09.2016	11.11.2021
KR 10-2310143 B1	Microstructured Organic Sensor Device and Method for Manufacturing same	B. Richter, P. Wartenberg, K. Fehse, M. Jahnel	09.05.2019	30.09.2021
KR 10-2326644 B1	Method for Operating a bi-directional Display	B. Richter, P. Wartenberg	17.04.2017	09.11.2021
EP 2 784 840 B1	Method of Manufacturing on organic Device	O. Hild, A. Philipp, T. Gil	27.04.2014	01.12.2021
DE 10 2018 113 251 B4	Verfahren zum Herstellen einer CdTe-Solarzelle	D. Hirsch, O. Zywitzki, T. Modes, T. Werner, T. Kopte, C. Metzner	04.06.2018	09.12.2021
EP 3 506 952 B1	Inactivation of Pathogens in biological Media	M. Thoma, K. Fischer, J. Portillo	31.08.2017	29.12.2021

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Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology FEP

Site Winterbergstraße

Winterbergstraße 28
01277 Dresden, Germany

Phone +49 351 2586-0
Fax +49 351 2586-105

Site Maria-Reiche-Straße

Maria-Reiche-Straße 2
01109 Dresden, Germany

Phone +49 351 8823-238
Fax +49 351 8823-394

Contact person

Annett Arnold, M.Sc.
Corporate Communications
Phone +49 351 2586-333
annett.arnold@fep.fraunhofer.de

Editors

Prof. Dr. Elizabeth von Hauff
Annett Arnold, M.Sc.

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Finn Hoyer

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Tim Ryan
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Highlights

Appointment of Dr. Gösta Mattausch as honorary professor at the West Saxon University of Applied Sciences Zwickau

Conference »pro flex 2021 – Roll-to-roll coating of flexible materials«

Workshop »Hygiene Technologies« in cooperation with Wirtschaftsförderung Sachsen GmbH

Fraunhofer Prize for a more efficient, faster and environmentally friendly manufacturing process for vaccines

Award for a Fraunhofer-wide best customer acquisition

Excellence Award for Philipp Wartenberg

Participation in the 5 km company run »REWE Team Challenge«

About Fraunhofer FEP

The Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology FEP works on innovative solutions in the fields of vacuum coating, surface treatment as well as organic semiconductors. The core competences electron beam technology, plasma-assisted large-area and precision coating, roll-to-roll technologies, development of technological key components as well as technologies for the organic electronics and IC/system design provide a basis for these activities. Thus, Fraunhofer FEP offers a wide range of possibilities for research, development and pilot production, especially for the processing, sterilization, structuring and refining of surfaces as well as OLED microdisplays, organic and inorganic sensors, optical filters and flexible OLED lighting. Our aim is to seize the innovation potential of the electron beam, plasma technology and organic electronics for new production processes and devices and to make it available for our customers.

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