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FEP

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

Annual Report 2023/24

Content

Prof. Dr. Elizabeth von Hauff,
Director Fraunhofer FEP

Foreword

Dear partners of the Fraunhofer FEP,
Dear readers,

2023 was a crisis-ridden year globally that brought many major challenges – from political turmoil and conflict to natural disasters – that culminated in diverse and complex economic uncertainty. However, despite all the hurdles, we at Fraunhofer FEP can look back on many positive developments as many of these external challenges presented opportunities.

Our outstanding energy management system and years of forward-looking conversion to sustainable energy supply solutions, such as photovoltaic modules for autonomous electricity production, use of waste heat from our large machines for heating office and lab space and smart solutions for local energy saving, have helped us get off to a good start this year despite rising energy prices. Thanks to the successful acquisition of numerous industrial projects and publicly funded projects by the FEP team, we were able to achieve a balanced economic result for the year.

In April we presented the institute strategy to external auditors from industry, academia, and politics. Regular strategy reviews are standard practice in the Fraunhofer Society. Preparations began in the fall of 2022 and involved several workshops that integrated the interdisciplinary teams and individual business units of the institute. The strategy report included the overarching institute vision and focus on sustainability, human resources, digitalization and scientific excellent. In addition, the business units Plasma Technology, Electron Beam Technologies, and Medical Biotechnology Applications presented detailed strategic plans. The strategy audit in 2023 kicked off continuing process in which the Fraunhofer FEP will monitor and re-examine the strategic focus of the institute annually, with a larger strategy audit every 5 years. In a very constructive exchange with the external consultants and auditors, our strategic focus was confirmed and the tools for future strategy evaluations were defined. In future, we will build on this audit for the ongoing strategic review of the institute. We would like to thank all colleagues involved, our external consultants and auditors for their support and the constructive discussion. As a result, we at Fraunhofer FEP will build on our existing strengths and unique selling points and to strategically position the institute towards current and emerging markets.

Our technological developments – particularly in the field of coating flexible products such as films or ultra-thin glass – are

increasingly being used in sustainable construction applications. We have been able to lay important foundations within several EU projects, including the development of thermochromic and electrochromic coatings for the building sector. The first prototypes of smart windows, as a contribution to reducing energy consumption in buildings, and hydrophilic coatings on ultra-thin glass from the Switch2Save, NewSkin and FLEX-G 4.0 projects met with a very positive response at our first participation at the BAU 2023 trade fair in Munich. In addition to the publicly funded projects, continuous research and development with leading industrial partners is leading to further pioneering advances in the field of sustainability.

After the first years, the sputter epitaxy working group at Fraunhofer FEP has established itself. For the second time, our institute organized an online workshop with numerous international experts and offered a platform for the exchange of current research results. We look forward to further developing our technological platform and network of partners in this field in coming years.

We see incredibly potential for our vast and unique expertise in the development of electron beam technologies for application in hydrogen technologies to support the energy transition. As an example of one of the many activities in this direction, we coated the first bipolar plates last year and optimized our system technology for this purpose. Our range of technologies for the production, storage and processing of hydrogen for the energy transition was presented very actively as part of our networking activities, e. g. in the Fraunhofer hydrogen network or with the Saxon cluster HZwo e.V., and also presented for the first time at regional and international conferences and trade fairs in Dresden and Brussels.

For a few years now, the Fraunhofer FEP is responsible for the Fraunhofer-business area Cleaning. This year was a special one for all members. Fraunhofer-business area Cleaning celebrated its 20th anniversary. The celebrations culminated at parts2clean with numerous activities and technical presentations as well as an anniversary breakfast.

The institute announced another highlight in the summer. Within the "Backplane" project funded by the Saxon State Ministry of Economic Affairs, Labor and Transport SMWA , colleagues from the Microdisplays and Sensors department realized OLED microdisplays in a 28-nanometer backplane technology on 300 mm wafers for the first time. This made it possible to produce components with a display diagonal of 0.18 inches and pixel sizes of just 2.5 micrometers. This corresponds to an as-yet unattained level in the global OLED microdisplay market and is world record.

Our expertise in the field of medical and biotechnological applications using the diverse effects of electron beams once again contributed to many projects in 2023. The expansion of our S1/S2 facilities to validate these processes and technologies are now possible in the new laboratories in our newly completed building that will house activities for electron beam technologies for environmental, medical, ecological, and sustainable applications. In order to create a solid basis for these activities, organizational adjustments were made to enhance the synergistic potential in the institute. We are using the momentum of this eventful year to start 2024 with the official inauguration of the new building on the RESET (Resource Saving Energy Technologies) campus next spring.

I would like to thank all our employees as well as our funding bodies and industry and academic partners for their continued great trust, support, and cooperation and a fantastic year in the face of the numerous external challenges we faced together!

In our annual report, we take a detailed look at the highlights of the last twelve months. I hope you enjoy reading it and look forward to continuing our good cooperation!

News from the Institute

Ceravis AG takes over E-Vita GmbH

The two founding shareholders of E-Vita GmbH, Ceravis AG and Fraunhofer-Gesellschaft e. V., announce that Ceravis has acquired all Fraunhofer shares in E-Vita with effect from June 30, 2023.

E-Vita GmbH was founded in 2021 by Ceravis and Fraunhofer as a joint venture to make the technology of chemical-free, sustainable treatment of seeds using electrons, which is already established in large-scale plants, economically viable for smaller seed quantities. The aim of the treatment is to eliminate bacteria, viruses and fungi on the surface of grains and other biological bulk goods.

Due to a strategic realignment of the business model by the management of E-Vita and the main shareholder Ceravis in the second half of 2022, the investment motive for Fraunhofer no longer applied, whereupon the shareholders of E-Vita mutually agreed to transfer the Fraunhofer shares to Ceravis and to terminate all contracts in connection with the originally planned development of the small-scale plants.

Ceravis, Fraunhofer and E-Vita will continue to cooperate in the field of electron treatment of seeds in the future.

Reorganization of activities in the field of medical-biotechnological applications

With its electron beam and plasma technologies, the Fraunhofer FEP has a diverse toolbox for a very broad application portfolio, which has also included medical applications for around 20 years.

In addition to the effect of thin films, for example for biocompatible or antimicrobial surfaces, accelerated electrons in particular provide unique possibilities for more effective vaccine production, gentle tissue preparation, hygienization and sterilization of medical products and hormetic stimulation of microorganisms for microbiological processes. In 2017, a separate "Medical and Biotechnological Applications" department was formed from the relevant working group to address these issues. Based on recommendations in the 2022/23 strategy process, to make better use of technological synergies and to stabilize this promising field of work, the activities of the 2023 division were reassigned to the working groups of the Electron Beam division.

In addition, a Biomedical Laboratory Unit is now available as an independent cross-sectional group to serve internal and external cell and microbiological as well as chemical analysis orders.

New building E on the RESET campus

In July 2023, the Fraunhofer FEP put a newly constructed research research building into operation. This is a central component of the RESET (**RES**ource-saving **E**nergy **T**echnologies) research campus between Bodenbacher Straße and Winterbergstraße. With this building, a flexible, expandable and sustainable building ensemble has been created.

This building is used for scientific operations in the clean room, biomedical laboratory area, the radiation protection area and the electron beam technology center and creates excellent working conditions for 35 people.

The Fraunhofer FEP is a leader within the Fraunhofer-Gesellschaft in the use of energy management systems and their practical application in operations. The technical equipment of the building was therefore designed with a focus on the resource-saving provision and use of all types of energy. Examples include:

- Extraction of cooling energy from groundwater
- Waste heat from the test facilities is used to heat the building (directly or by means of a heat pump)
- Air conditioning of the laboratories/clean room by means of adiabatic exhaust air humidification
- All lighting is LED
- Regulation/control of the technology using a weather forecast tool
- In-house power generation with PV system

New Head of Administration at Fraunhofer FEP

After 12 years as Head of Administration at Fraunhofer FEP, Veit Mittag handed over the baton to Almar Schulz-Coppi in September 2023.

From January 1, 2012, Veit Mittag headed the administration with its associated units such as Human Resources, Information Technology, Controlling, Purchasing and Export, Technology and Quality Management as well as Team Assistance.

During his time, he oversaw the integration of the Fraunhofer COMEDD facility and led the institute through many ups and downs on the administrative side. Under his leadership, the Fraunhofer FEP expanded its space with the new buildings at Bodenbacher Straße 31 and, together with the institute management and his team, developed forward-looking measures to cope with difficult economic times, during the pandemic or the energy crisis.

By March 2024, the administrative management will be handed over to Mr. Almar Schulz-Coppi. Mr. Schulz-Coppi brings a wealth of experience from the industry and looks forward to the challenges and tasks ahead with confidence and enthusiasm.

We would like to thank Mr. Veit Mittag for his achievements and his work at Fraunhofer FEP. We wish Mr. Schulz-Coppi every success in his new position.

Strategy

Participants of the strategy audit

Strategy audit of the Fraunhofer FEP

A systematic examination of the future and the future viability of the institutes takes place regularly at the Fraunhofer-Gesellschaft as part of strategy processes. In this process, the institutes examine trends, developments and market shifts in order to open up new fields of application, further develop the R&D portfolio and anticipate new markets. In the Fraunhofer strategy process, the readjustment of the position and profile of the institutes is brought together by interlinking the various levels of strategy development and integration into the day-to-day work of the institutes.

Following the change in institute management, Fraunhofer FEP launched a strategy process for the first time since 2016, culminating in a strategy audit in April 2023. In addition to the overall strategy, thematic focal points and various aspects of the institute's culture were examined. The auditors encouraged the Fraunhofer FEP to consistently drive forward the further development of the culture as a common space for action.

Valuable insights were gained from the strategy process and the audit, which have already led to short-term changes in the organizational structure and in the particular focus on strategic research fields.

The Fraunhofer FEP will now subject the institute's strategic orientation to an annual internal review as part of a rolling strategy process.

The institute would like to thank all auditors for their committed participation and their helpful questions and suggestions:

- Prof. Dr. Michael Albrecht, Universitätsklinikum Carl Gustav Carus an der Technischen Universität Dresden
- Prof. Dr. André Anders, Leibniz Institute of Surface Engineering
- Dr. Bernd Fischer, DR. JOHANNES HEIDENHAIN GmbH
- Tobias Hackl, Carl Zeiss SMT GmbH
- Dr. Ilona Jipa, Dr. Ing. h.c. F. Porsche AG
- Prof. Dr. Christoph Leyens, Fraunhofer Institute for Material and Beam Technology IWS
- Dr. Neil Morrison, Applied Materials WEB Coating GmbH
- Dr. Martin Pfeiffer-Jacob, Heliatek GmbH
- Dr. Holger Pröhl, VON ARDENNE GmbH
- Michael von Papen, Pharmatec GmbH
- Prof. Dr. Katrin Salchert, University of Applied Sciences HTW Dresden
- Dr. Michael Zeuner, scia Systems GmbH

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Advisory Board

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Prof. Dr. Herwig Buchholz
Chairman of the Board

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

Photo of the 34th Advisory Board Meeting on April 25, 2023.

Members of the Advisory Board

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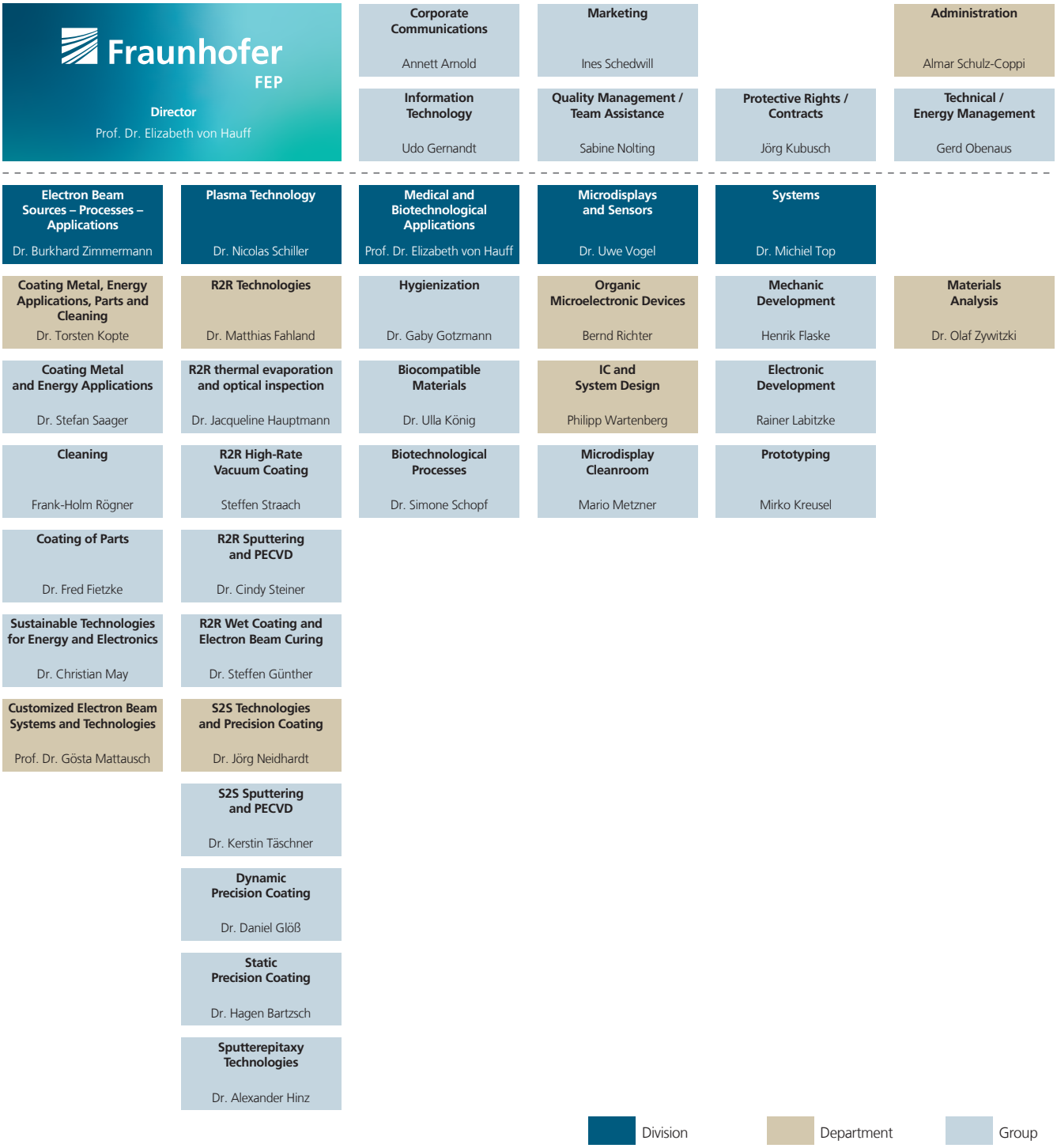
Fraunhofer-Gesellschaft, Institute Liaison

Dr. Ulrike Geiger
Federal Ministry of Education and Research
Head of Division "Quantentechnologien; Quantum Computing"

This list represents the status as of the board meeting in 2023. For an up-to-date version, please visit our website at:

https://s.fhg.de/NX2

Organizational Structure



The organizational structure shown represents the status as of 09/2023. 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 11.6 million € of new business from industry through direct contracts. Proceeds of 6.2 million € were obtained from public projects funded by the federal and state governments. A portion of these, amounting to 1.4 million €, was attracted through joint publicly funded projects with mid-cap companies. The expenditure of institutional capital ran to 12.8 million €.

Investment costs

Total expenditures from the operating and investment budget amounted to 30.7 million €. 2.1 million € was invested in equipment, construction and infrastructure during the period.

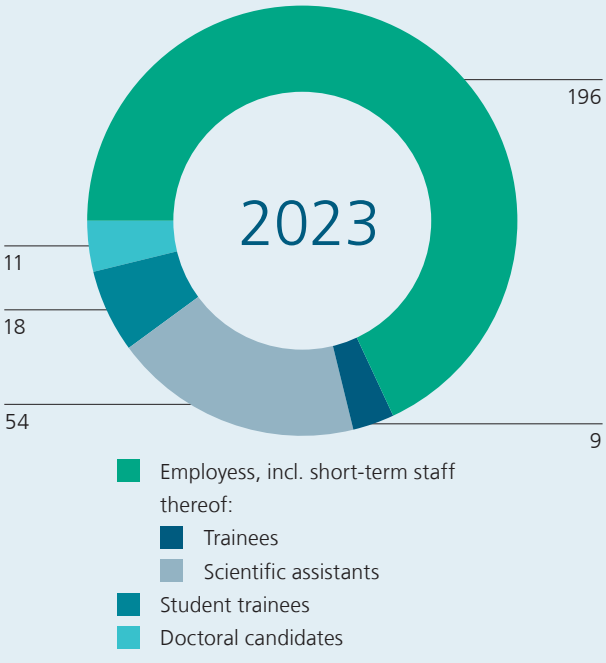
Employee development

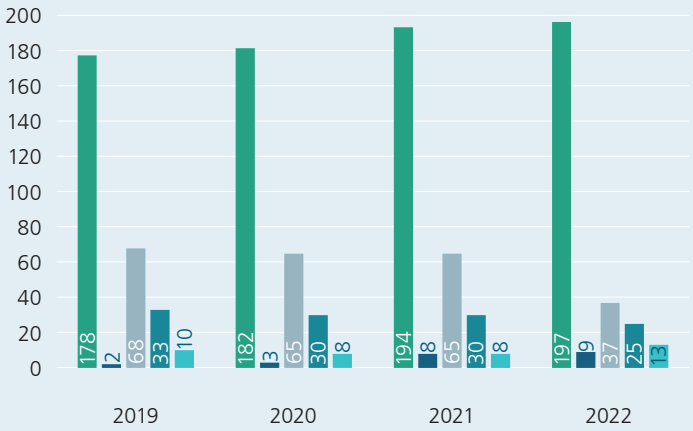
196 staff members were employed at the institute during the past year, of which 9 were trainees, along with 18 student trainees as well as 54 scientific assistants. Of the 72 staff members that were employed as scientists, 11 were additionally working on their doctoral degrees. The proportion of females in the scientific area amounted to 25 percent.

Staff and material costs

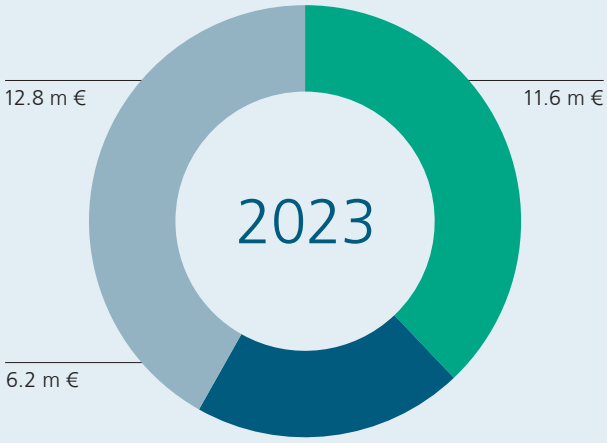
Personnel expenditures totaled 15.4 million €, representing 53.9 percent of the operating budget (28.6 million €). Material costs amounted to 13.2 million €.

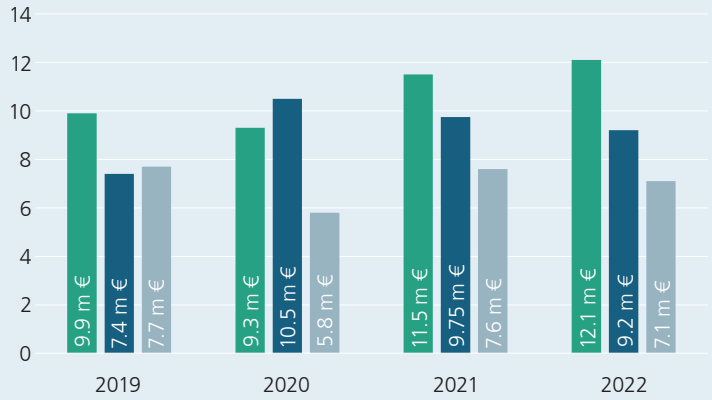
Employee development





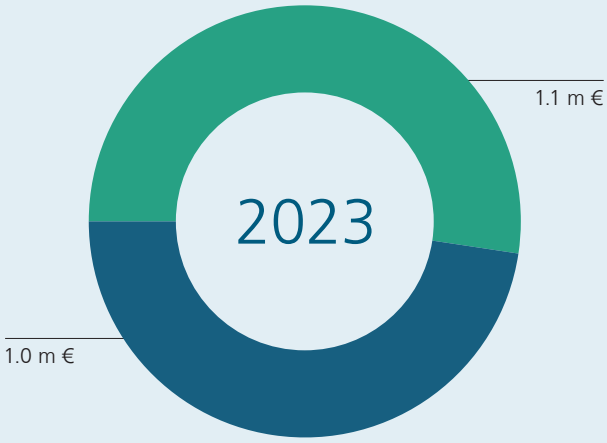
Financing

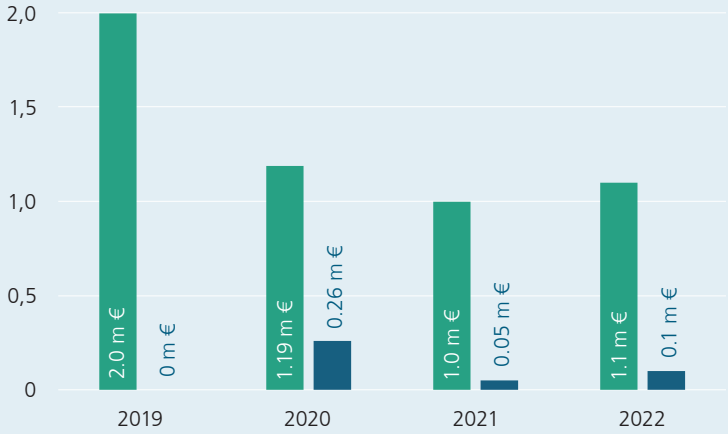




- Commercial proceeds
- Public/EU and misc. proceeds
- Basic funding

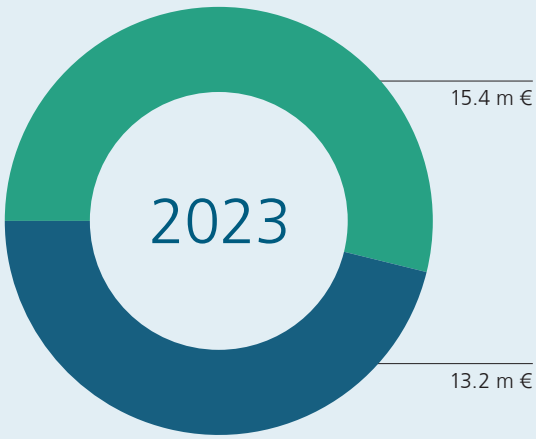
Investment costs

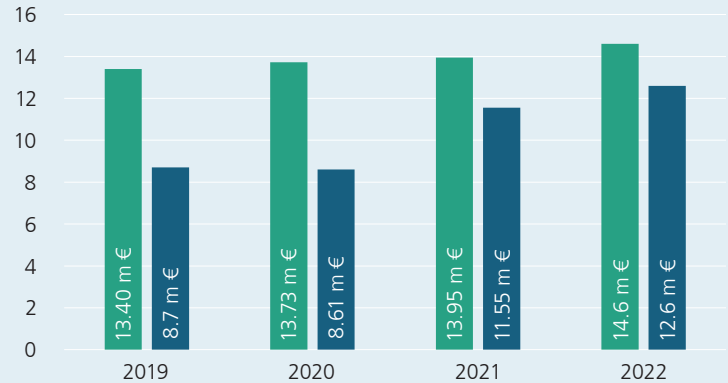




- Normal investment
- Strategic investment

Staff and materials costs

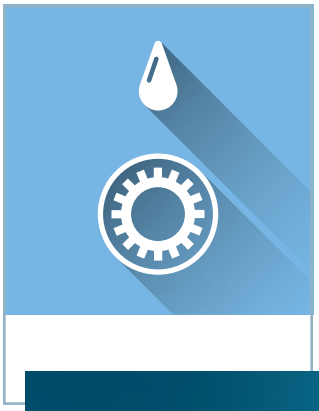


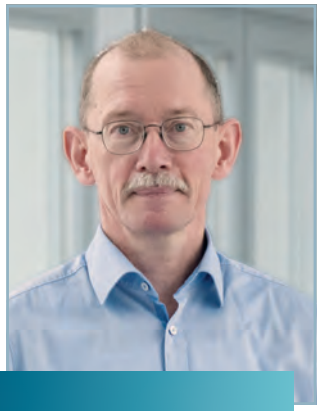


- Personnel expenditures
- Material costs

Research News

Business Units





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Coating of Metal Sheets and Strips, Energy Technologies

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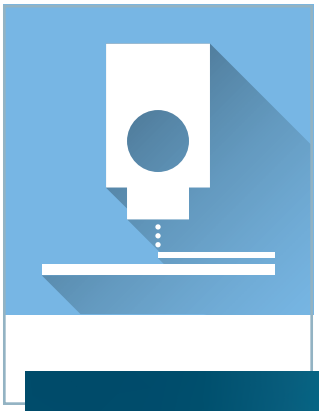

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Coating of Parts

The PVD coating of tools and components with friction and wear reducing layers as well as for corrosion protection has a long tradition at Fraunhofer FEP. For applications in consumer goods, energy and medical technology, coatings with specific optical and electrical properties, biocompatibility, scratch and abrasion resistance are also deposited. In this context, the adjustment of specific wetting properties such as complete coverage (superhydrophilicity) or their complete suppression (superhydrophobicity) is becoming increasingly important and requires unconventional solutions.

A special application with a unique selling point is the coating of small parts as bulk material, e. g. for the corrosion protection of fasteners or the functionalization of granulates and powders.

In addition to pulse magnetron sputtering in single, double and multiple source configurations, high-rate electron beam and thermal evaporation as well as combinations of these processes are used as coating technologies. Another focus is the development and application of plasma sources for substrate pre-treatment as well as physical and chemical vapor phase deposition.

Can it be a little thicker? PVD deposition of molybdenum layers

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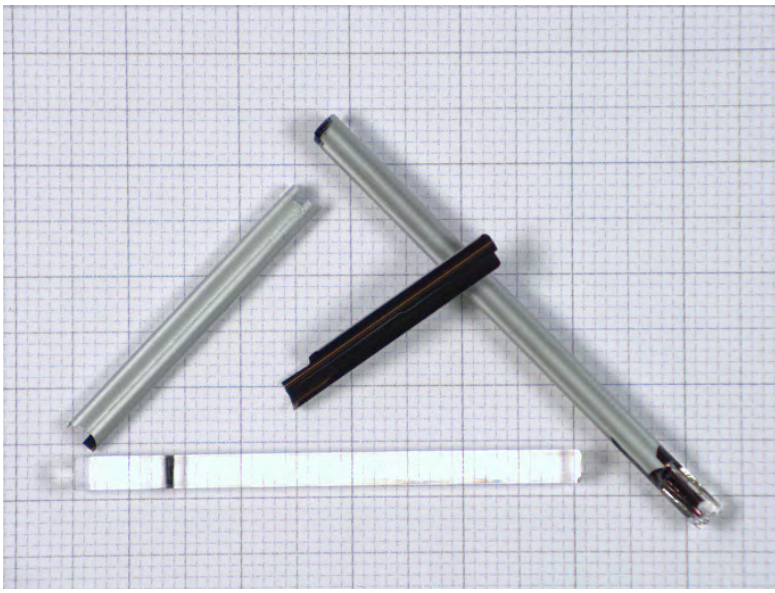
In this project we focus on the high-rate deposition of thick molybdenum layers. The extent to which this can be used as an alternative production method for filigree components made from this thermally and mechanically highly resistant metal is being investigated.



Mo-tube detached from the glass rod and half-shell with interface layer

Molybdenum as a material and as a coating

The production of fine sheets or tubes from molybdenum is technically difficult, given that molybdenum has to be processed at high temperatures. Forming takes place at a temperature of 700°C, often followed by annealing steps at 1000°C or at even higher temperature. Because the metal exhibits brittle behaviour when more than 100 ppm of oxygen are included, all steps must be carried out under inert gas atmosphere. Altogether, this results in high energy consumption and high production costs. Due to its properties, the metal is also not suitable for powder-based additive manufacturing.

An alternative way to produce filigree components made of molybdenum could be to deposit thick layers of the material on a supporting structure made of easy-to-machine base material with subsequent separation of the support and the layer. In order to achieve components with sufficient stability, comparatively thick layers need to be deposited.

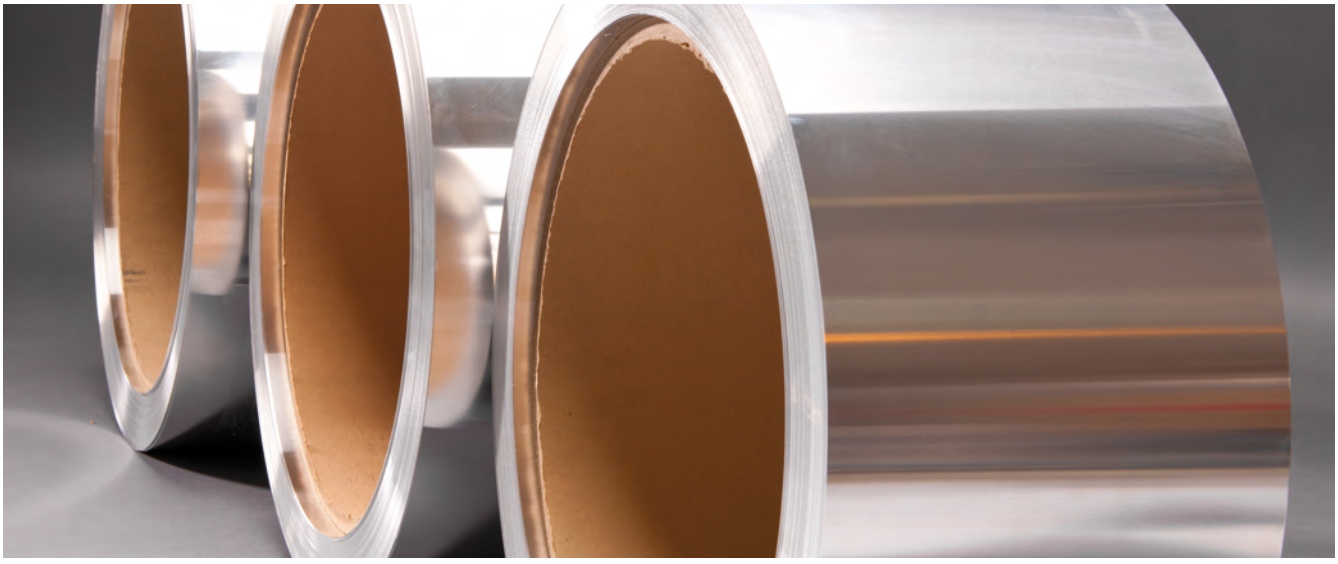
The Coating Components Group has investigated the deposition of thick molybdenum layers, facing the challenge of creating a dense, pore-free structure. At the same time, the stresses in the coating, or in the coating-substrate composite, must not become too big in order to avoid stress-induced coating failure or substrate damage.

In pulse magnetron sputtering, in addition to the working pressure and the deposition temperature, the choice of pulse parameters represents an additional way of influencing the microstructure and the internal stresses of the resulting layers. If these are changed in the course of the layer build-up, a stress profile can be generated that ensures the integrity of even thick layers. With these measures, molybdenum layers up to 50 µm thick have been deposited to date. In order to minimize thermally induced stresses caused by the different expansion coefficients of the substrate and the coating, a suitable substrate material must also be selected. So far, glass has proven to be a good substrate to which molybdenum adheres very well. So well, in fact, that a thin intermediate layer must be created, which specifically weakens the layer-substrate interface, to separate the filigree components. The non-destructive separation of component and support structure is currently in the focus of the project work.

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.



Innovative technologies for the production, storage and processing of hydrogen

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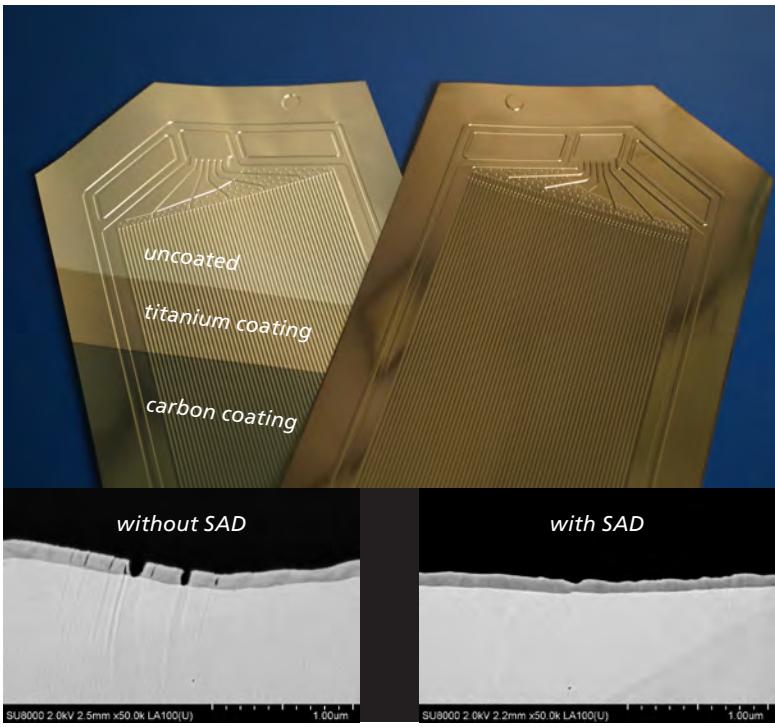
At Fraunhofer FEP, a pilot plant for coating bipolar plates for electrolyzers and fuel cells has been qualified. This technology is cost-effective and enables high productivity as a contribution to the success of the energy transition.

Highly productive and cost-effective production technologies are required to successfully ramp up the hydrogen economy. To this end, the in-line vacuum coating plant MAXI for plasma-activated electron beam evaporation using spotless arc-activated deposition (SAD) was qualified for the highly productive and efficient coating of bipolar plates for electrolyzes and fuel cells.

Bipolar plates have to perform with long-term stability in a chemically aggressive environment and require protective coatings such as titanium. At the same time, sufficient electrical conductivity must be ensured, for example by an additional carbon coating.

Using plasma-activated electron beam physical vapor deposition, for example, ductile, formable coatings can be applied to metal strip before it is stamped into bipolar plates. Coating the material prior to the embossing process is considered as a decisive step for upscaling production in the roll-to-roll process. One challenge for formability is to ensure a dense macrostructure.

These layer properties can be realized by the processes such as SAD developed at Fraunhofer FEP, and with the plant MAXI, an innovative roll-to-roll as well as sheet-to-sheet line for the high-rate coating of corresponding substrates is available for research and development as well as for pilot production. Initial results in the coating of 250 mm wide and 50 µm thick metallic strips with titanium already exhibited homogeneous layers in the thickness range of 100 nm with a dense structure, which could be produced at strip speeds of 10 m/min. The advantage of this process is that the substrate temperature can be limited to maximum values of less than 250°C. This means that the temperature can be kept to a minimum. Furthermore, due to the low heat load, sensitive materials such as electrically conductive polymers can be coated, which represent an innovative alternative for batteries and fuel cells.



Bipolar plates with coatings (top) and cross-sections of approx. 100 nm titanium layers after 180° bending test (bottom)

The research activities were carried out in close cooperation with Fraunhofer IWU and VON ARDENNE GmbH.

Development of 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 evaporation (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. Antimicrobial and fungicidal actions of electrons represent biological use effects. 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 facilitates the biocompatible functionalization of implants and the 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.

Project "ARA": Degradation of pharmaceutical pollutions through wastewater treatment with low-energy electrons

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In the joint project "ARA", Fraunhofer FEP and CREAVAC GmbH demonstrated the degradation of pharmaceutical pollutions through combined wastewater treatment with low-energy electrons and ozone for improved biodegradability.

Due to their increased use in medicine and inadequate degradation in conventional wastewater treatment plants, ever higher concentrations of hormones, antibiotics and X-ray contrast agents can be detected in the environment and thus also find their way into the food chain and drinking water.

The harmful effects of these micropollutants on the human organism are the subject of current research. The mechanisms of action are not yet fully understood, but there are serious indications that point, for example, to a reduction in fertility, an increase in certain cancers and the emergence of antibiotic resistance.

In the "ARA" research project funded by the Saxon State Ministry of Economic Affairs, Labor and Transport, the joint partners Fraunhofer FEP and CREAVAC GmbH therefore set themselves the goal of developing a new type of treatment process that significantly improves the degradation of persistent micropollutants.

For this purpose, the laboratory prototype of a hybrid treatment module was developed, tested and optimized, which combines the irradiation of a thin liquid stream by low-energy electrons with ozone treatment.

The hybrid treatment module was designed to be so compact, that (after appropriate upscaling) it will enable the local pre-treatment of wastewater from so-called point emitters (such as hospitals and pharmaceutical companies) in an economical and energy-efficient manner in the future.

This aims at an effective, broadband transformation or splitting of the micropollutants in order to make them more degradable for downstream biological treatment stages of conventional wastewater treatment plants.

Integration of the ARA module for the combined treatment of liquids with low-energy electrons and ozone (top right) in the REAMODE laboratory plant (left). Simulation of the biodegradability of the transformation products in a laboratory wastewater treatment unit (bottom right).

The module was integrated into the FEP test plant REAMODE. In this laboratory setup, partial building blocks of the new treatment concept were first examined separately and then optimized as a system. This included the functionality of all components and their control, the generation of ozone and its injection into the liquid to be treated, the shaping of the fluid flow as well as the homogenization and dosimetric quantification of the energy input into the liquid irradiated with low-energy electrons.

The superior treatment success compared to known methods (such as activated carbon filtration or UV irradiation) was demonstrated using selected test substances. These were treated in synthetic test wastewater and then subjected to analysis by High-performance liquid chromatography and a simulation of the biodegradability of the transformation products in a laboratory wastewater purification unit with activated sludge from a municipal wastewater facility. Following the successful completion of the project, an upscaling of the concept and expansion of its field of application is now envisaged, e.g., to the purification of wastewater from the chemical industry or agriculture, where the simultaneous inactivation of pathogens is of additional value and expected.

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Europäischer Fonds für regionale Entwicklung
Europäische Union
Diese Maßnahme wird mitfinanziert durch Steuermittel auf der Grundlage des vom Sächsischen Landtag beschlossenen Haushaltes.

Funded by the Saxon State Ministry for Economics, Labour and Transport. Funding reference: 100534392/100534386

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.

Windows with switchable properties

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Over a period of four years, Fraunhofer FEP has coordinated the Horizon 2020 project Switch2Save (Lightweight switchable smart solutions for energy saving large windows and glass facades).

In this project, ten partners from seven European countries came together to develop new approaches for energy-efficient office buildings. The solutions aimed to equip the windows of existing buildings with surfaces that can adapt their properties to external environmental influences. The transparency can be changed so that as much of the incoming sunlight as possible reaches the interior in order to support the heating in cold weather. In the opposite case, on warm summer days, the light is largely prevented from passing through the window, which in turn helps to reduce the load on the air conditioning system. The researchers always kept in mind that the coating solutions can be applied to lightweight and flexible substrates. This means that the coated films can later be easily integrated into existing windows.

This approach was flanked by theoretical considerations. Building simulations for various climatic conditions present in Europe revealed that the new solutions are particularly important for cooling interior spaces. This means that they are primarily important in southern countries, even outside Europe. However, highly insulated buildings with large window areas also have a high cooling requirement in Central and Northern Europe, which is why switchable coatings can also make a contribution to energy efficiency there. This is becoming increasingly important, particularly against the backdrop of global warming.

The Fraunhofer FEP was primarily responsible for the thermochromic coatings. This special variant of switchable windows does not require any additional controls. It reacts solely to the ambient temperature. Here the Fraunhofer FEP has made great technological progress. For the first time, this sophisticated technology has been successfully implemented as a continuous roll-to-roll process. Thanks to sophisticated sensor technology, it was possible to draw conclusions about the subsequent properties of the coatings during the process. Even though thermochromism did not make it into the final demonstrators, important insights were gained into application scenarios and remaining technical challenges.

Wirkung von elektrochromen Fenstern am Beispiel eines Zimmers im Krankenhaus Nikaia Agios Panteleimon, Griechenland

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme.
Funding reference: 862100

Medical and Biotechnological Applications

Sustainable developments serve the long-term preservation of global resources and are strengthened by interdisciplinary cooperation in science, so that innovative strategies for current challenges such as climate change, resource scarcity or water pollution can be realized. We work on the elaboration of sustainable technological solutions by needs-based process development along the value chain of a product. As a result, we open up socially relevant fields of application in the MedTech, HealthTech and BioTech sectors. The need for bio-based substitution processes and materials or sustainable infection protection measures is the basis of our research activities.

Pandemic situations have highlighted the importance of hygiene technologies. We are researching sustainable technologies with an efficient disinfection effect using ionizing radiation or antimicrobial coating systems. By means of adaptive surface engineering, we produce bio-based materials with selective characteristics profiles using low-energy accelerated electrons. The system-specific further development of low-energy electron beam technology for aqueous systems is progressing continuously. Of particular note are the latest developments in liquid and particle dosimetry for the associated process monitoring. The new biomedical laboratory complex offers excellent internal and external R&D services and operates in accordance with QM guidelines.

Improved infection protection by bio-based surface functionalization of textiles using low-energy electron beam technology

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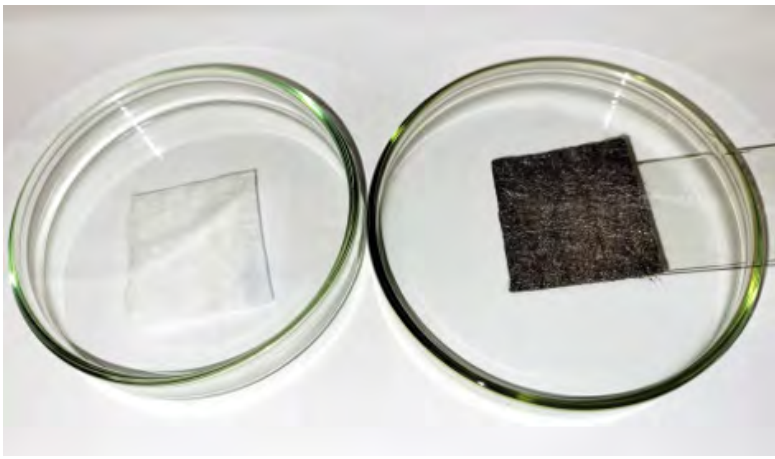
Electron beam technology can be used to create selective surface properties. In the HuminTex project, sustainable respiratory masks consisting of biodegradable nonwovens are functionalized with antiviral, naturally occurring humic substances.



Textile materials before and after the immobilization of antiviral humic substances by means of Ebeam-Grafting

Pandemic situations such as the global outbreak of Covid-19 cause complex problems for preventive health care. Technical, organizational and personal protective measures must be taken to minimize the risk of infection. Respiratory masks are an effective infection protection. On the one hand, careless handling of used masks carries an unintentional risk of infection. On the other hand, improper disposal increase the global plastic waste problem. This correlation demonstrates the urgent need for sustainable infection control concepts.

One approach to prevent infection is the immediate virus inactivation when viruses come in contact with the surface of the mask material. The aim of the HuminTex project is therefore to functionalize textile surfaces for the production of particle-filtering respiratory masks with antivirally effective and naturally occurring humic substances. Furthermore, the ecological compatibility of the masks is to be optimized by reducing the consumption of resources and improving environmental performance. For this reason, biodegradable textiles are used for mask production.

In order to achieve a high durability and reliability of the antiviral functional coating, the humic substances are to be covalently bound to the textile surface. Therefore, the HuminTex project is investigating the suitability of low-energy, non-thermal electron beam technology (Ebeam) for the first time at the Fraunhofer FEP compared to a wet-chemical technology.

The Ebeam-based, two-stage coating process, Ebeam-Grafting, enables materials to be equipped with surface-selective characteristics, whereby all process parameters can be individually monitored and modularly adapted. Ebeam-Grafting can be used for material-gentle and environmental-friendly surface modification. Subsequently, the antiviral efficacy of the surface-modified nonwovens can be evaluated complementary in the biomedical FEP laboratory complex.

In addition, the technological prerequisites for the general development and industrial production of antiviral protective textiles for the health and medical sector are to be created.

Supported by:

Federal Ministry for Economic Affairs and Climate Action

Funded by the Federal Ministry for Economic Affairs and Climate Protection. Funding reference: 16PS104004

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, inorganic µLED, that become integrated with 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.

World record – OLED microdisplay with 10,000 dpi in 28 nm technology

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Within SMWA-funded project BACKPLANE we have researched high-resolution OLED microdisplays at 0.18" screen diagonale and shown a prototype at pixel size of 2.5 µm and pixel density of 10,000 dpi – world-record!

OLED microdisplay with a resolution of 1440 × 1080 pixels and the world's smallest pixels of 2.5 micrometers

The continuous microdisplay improvements in recent years have been driven by various requirements such as pixel density, energy efficiency, color, brightness, or frame rate. We have developed a wide range of microdisplays in full-color or monochrome, from ultra-low power versions to high-resolution variants for the use in augmented- (AR) and virtual-reality (VR) applications and other wearables.

The majority of microdisplays on the market are currently developed and manufactured on 200 mm wafers in 250 nm to 90 nm CMOS process nodes. The manufacturing of microdisplays on 300 mm wafers has been rare so far.

However, market requirements for image quality, pixel density and integrated functionality are continuously increasing. Therefore, Fraunhofer researchers have been examining the scaling effects in smaller CMOS technologies and investigating the use of 300 mm backplane processes as part of the "Backplane" project funded by the SMWA. In this context, the researchers have now succeeded in making the next major leap forward in development: For the first time, they realized an OLED microdisplay with tiny 2.5 µm pixels (corresponding to 10,000 dpi) at a display diagonal of 0.18 inch. This demonstrated the feasibility of developing displays based on 28 nm small-node technology on 300 mm wafers and realized the world's smallest pixels of an OLED microdisplay.

The newly developed OLED microdisplays have a resolution of 1440 × 1080 pixels in monochrome or 720 × 540 pixels in full color. On the one hand, the flexible display architecture allows the refresh rate to be reduced to 0 Hz in extreme cases when the display content remains unchanged, thus avoiding all unnecessary data transfer - an enormous advantage for power consumption. Conventional displays require a minimum refresh rate here, regardless of content. On the other hand, the new microdisplay also allows frame rates of up to 480 Hz in extreme cases – internally even up to several kHz.

Depending on the design, the new displays can be used in lifestyle products such as sports glasses or as head-mounted displays in motorcycle helmets, in industrial scenarios for wearables in logistics or for remote maintenance solutions. The now even smaller dimensions pave the way for even more ergonomic systems.

Funded by the Saxon State Ministry for Economics, Labour and Transport. Funding reference: 100392259

Precision Coating

Precision surface functionalization is essential for a wide range of applications. This requires very good homogeneity of layer thicknesses (less than ±0.5%) over extended substrate width and precise adjustment of mechanical, optical, electronic, and other layer properties. Core competencies in this area include adapted magnetron sputter sources, adapted in-line system concepts, process understanding for wafer and glass coating, dynamic apertures, energy-efficient flash lamp annealing and novel process technologies for ultra-thin glass. These competencies enable developments from »feasibility demonstration« to prototypes and »scalability demonstration«.

Examples of applications include:

- Large-area optical layer systems, also laterally or vertically graded
- Adapted transparent conductive contact layers including in-line flash lamp annealing
- Piezoelectric and ferroelectric layers for microsystems, high-frequency filters, ultrasonic microscopy, non-volatile storage, and micro-energy harvesting
- TiO_2 layers with photocatalytic, antimicrobial, and superhydrophilic properties
- Epitaxial AlN and GaN layers for power and RF electronics as well as LEDs

Large-scale vacuum functionalization of flexible ultra-thin glass on a pilot scale

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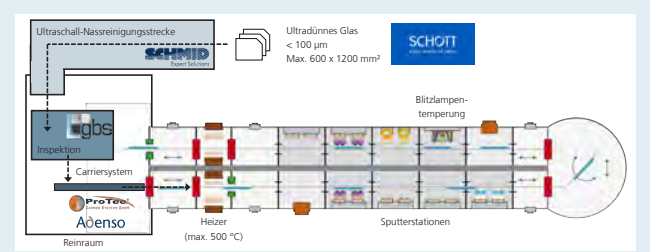
The Fraunhofer FEP addresses application development for ultra-thin glass with an in-line process chain for vacuum functionalization on a pilot scale. This consists of substrate cleaning, handling, inspection and electro-static chucking in an in-line vacuum process.

An in-line process chain for surface engineering of flexible ultra-thin glass was set as part of the BMBF-funded Glass4Flex project (Funding reference 13N14615). It enables the processing and vertical in-line vacuum coating of this innovative substrate material on a pilot scale up to a size of 1200 × 600 mm² and consists of the following components:

- Ultrasonic wet cleaning (SCHMID GmbH): mildly alkaline ultrasonic true in-line process with DI water rinsing and drying station with output to a class 6 cleanroom.
- Transfer station (Adenso GmbH): air cushion transport of the glass from the cleaning output to the e-chuck for precise positioning and fixation of the glass in preparation for the electric chucking process.
- Electrostatic chuck system (ProTech GmbH): fixing the substrate for transport in a vertical in-line vacuum chamber without any front or edge surface contact. Equipped with in-line control of the chucking voltage for adaption to various plasma processing steps.
- Glass inspection using white light interferometry (GBS GmbH): incl. large-area rapid scanning of the full glass surfaces to detect particles or defects followed by precise imaging of the areas of interest.

The processing of flexible ultra-thin glass using this pilot line enables precise, reliable, reproducible and homogeneous coating in the ILA 900 vertical in-line vacuum coating system under production relevant conditions. Optical layer stacks as well as transparent conductive and/or metallic films can be applied for a wide range of applications, e. g. in optics, sensors, electronics or display technology. Another unique feature is the directly in-line integrated station for flash lamp annealing for cost-efficient and resource-saving annealing of surfaces and coatings. The thin glass process chain, thus, offers a pioneering technology platform for the development, demonstration and piloting of a wide range of process and application options for thin layers and modified surfaces on ultra-thin flexible glass down to a minimum thickness of 30 µm.

E-chuck transfer of the three-part electrostatic chuck system for 600 × 1200 mm² substrates onto the carrier of the vertical in-line coating system



Pilotline for coating of ultra-thin glass up to 600 × 1200 mm²

Supported by:

Federal Ministry of Education and Research

Funded by the Federal Ministry of Education and Research. Funding reference: 13N14615

Systems

Technology and hardware development go hand in hand at Fraunhofer FEP. Electron beam and plasma components required within the institute are often not available in the market and are specifically modified and further developed to meet new application requirements. The development and implementation of the hardware components takes place within the "Systems" department. Equipped with mechanical and electronic development as well as the associated pilot production, we are able to map an idea from conception to development to implementation.

The internal development of our hardware allows for close collaboration with process engineers throughout the entire development process. This enables iterative processes and allows us to quickly achieve our goal: process and hardware transfer to the industry. Supporting activities in process development enable continuous improvement of the key components of Fraunhofer FEP.

Plasma and electron beam sources for a wide range of applications are part of our technological key component development portfolio. Our key components are already widely used in industry together with the technologies developed at Fraunhofer FEP.

Electrons as a sustainable alternative to chemical seed treatment

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The treatment of seeds using accelerated electrons is a sustainable alternative to chemical dressing. The ISABEL mobile plant platform was successfully developed further in 2023.

For over 25 years, the gentle treatment of seeds using accelerated electrons as a sustainable alternative to chemical dressing has been an important field of work at Fraunhofer FEP. The process developed at our institute uses low-energy electrons to kill pathogens in the seed coat permanently and without the development of resistant germs, while the embryo remains unaffected. The process works purely physically, so there is no toxic dust, contamination of soil and groundwater or chemical residues, meaning that seeds that have not been spread can be fed to livestock without hesitation, for example.

Fraunhofer FEP has developed the container-based ISABEL system platform to easily integrate the technology into existing processing steps. Such a system can be used stationary on site at wholesalers or mobile to serve various locations of smaller seed companies. Since the delivery of two ISABEL plants to seed producers, most recently in 2018 to BayWa AG's seed center in Hainichen, Fraunhofer FEP has gained valuable experience on process and system performance in close cooperation with the end users. Based on this, we successfully further developed our ISABEL mobile plant platform in 2022/2023 and were able to transfer the technology to another customer with a new pilot plant.

The electron treatment of seeds is an outstanding example of the process-oriented development of hardware at the Fraunhofer FEP. The optimization of electron sources, for example, requires a deep understanding of mechanical, electrical and physical properties and effects. At the same time, system engineering expertise and process experience from specific applications are necessary in order to transfer the technology into a system suitable for production. The close cooperation

The ISABEL mobile system platform can be easily transported to the end customer as a container

between the "Special EB Systems and Technologies" department and the "Systems" division enabled targeted advancements not only of the electron sources, but also of the overall system and technology.

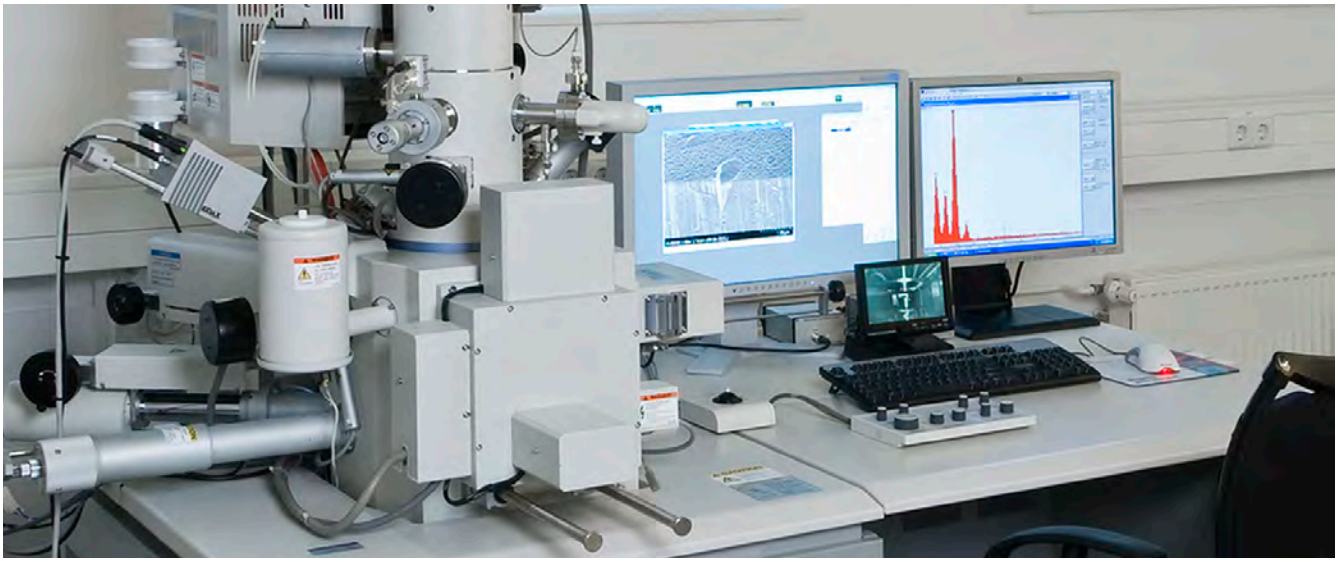
In 2024, the Fraunhofer FEP will continue to work actively with various partners on the development of the physical and biological treatment of seeds. Both in industrial contracts and in publicly funded projects, we are making our contribution to sustainability in agriculture.

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.



New possibilities for determination of water vapor permeability / transmission rate of coated polymer films

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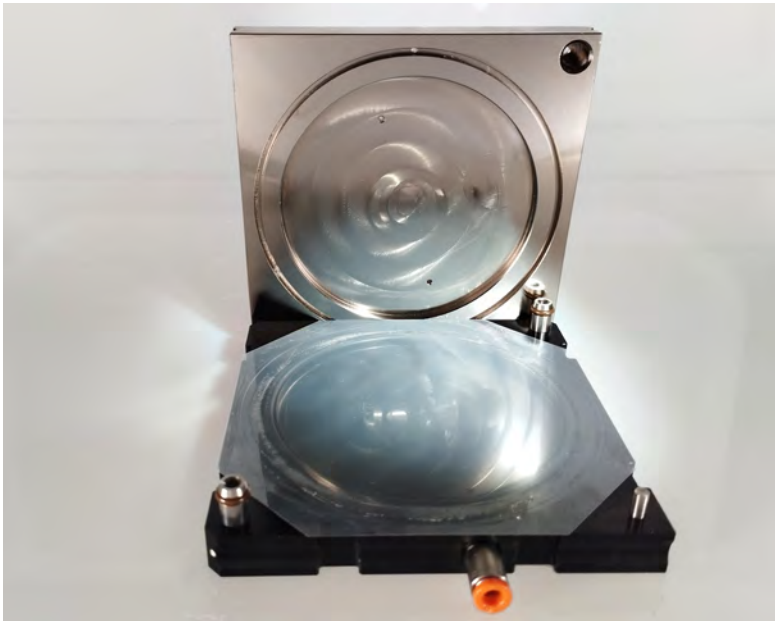
The accurate determination of water vapor permeability is a prerequisite for the development of tailor-made encapsulation films for a wide range of requirements. Fraunhofer FEP has extensive measuring methods and the necessary experience for this.



WVTR permeation cell with a coated polymer film

Barrier layers on polymer films are required to reduce the water vapor transmission rate (WVTR) for food packaging, electronic components, and flexible solar cells to achieve sufficient durability or lifetime. Depending on the application, the requirements for WVTR values vary greatly and range from less than 5×10^{-4} g/m²d for flexible solar cells to 1 g/m²d for food packaging.

When determining the water vapor transmission rate according to ISO 15106-3, the amount of permeated water vapor is registered with an electrolysis cell. The measured electrolysis current is directly proportional to the WVTR, so that a determination is possible without additional calibration. By investing in a new measuring device (Aquatran 3; Mocon), we can now also detect very low WVTR values of 5×10^{-5} g/m²d. The upper measuring limit of the available measuring devices (WDDG, Brugger) is a WVTR value of 10 g/m²d, so that a very wide WVTR measuring range for a broad variety of applications is completely covered.

Supplementary to the electrolysis method, we also have another measurement device (HiBarSens 2.0 HT, Sempa) in which the WVTR is determined by laser diode spectroscopy of a water vapor absorption band. Depending on the measurement mode used, very low detection limits of 1×10^{-5} g/m²d (diffusion mode) or 1×10^{-4} g/m²d (carrier gas mode) can also be achieved with this method. In addition, the temperature of the permeation cell can be varied in the range from 10°C to 85°C, allowing the investigation of influence of temperature on permeation. Determining the WVTR values at different temperatures allows additionally the evaluation of the activation energy for permeation. The measurement time required for permeation to reach equilibrium can be reduced by increasing temperature, which increases the effectivity of the measurements.

Thanks to our extensive measurement technology and experience, we can effectively and precisely measure the water vapor permeability of coated polymer films for a wide range of requirements. Determining the WVTR values as a function of temperature additionally enables a better understanding of the occurring permeation mechanisms.

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. A trailblazer and trendsetter in innovative developments and research excellence, the Fraunhofer-Gesellschaft supports science and industry with inspiring ideas and sustainable scientific and technological solutions and is helping shape our society and our future.

At the Fraunhofer-Gesellschaft, interdisciplinary research teams work with partners from industry and government to turn pioneering ideas into innovative technologies, coordinate and implement system-relevant research projects and strengthen the German and European economies with a commitment to value creation that is based on ethical values. International collaboration with outstanding research partners and companies from around the world brings the Fraunhofer-Gesellschaft into direct contact with the most prominent scientific communities and most influential economic regions.

Founded in 1949, the Fraunhofer-Gesellschaft currently operates 76 institutes and research units throughout Germany. Currently around 30,800 employees, predominantly scientists and engineers, work with an annual research budget of about 3.0 billion euros, 2.6 billion euros of which is designated as contract research. Around two thirds of Fraunhofer contract research revenue is generated from industry contracts and publicly funded research projects. The German federal and state governments contribute around another third as base funding, enabling the Fraunhofer institutes to develop solutions now to problems that will drastically impact industry and society in the near future.

The impact of applied research goes far beyond the direct benefits to the client. Fraunhofer institutes strengthen companies' performance and efficiency and promote the acceptance of new technologies within society while also training the future generation of scientists and engineers that the economy so urgently requires.

As a scientific organization, the key to our success is highly motivated employees engaged in cutting-edge research. Fraunhofer therefore offers its researchers the opportunity to undertake independent, creative and, at the same time, targeted work. We help our employees develop professional and personal skills that will enable them to take up positions of responsibility within Fraunhofer itself or at universities, within

industry and in society at large. Students involved in projects at Fraunhofer institutes have excellent career prospects on account of the practical vocational training they enjoy and the opportunity to interact with contract partners at an early stage in their career.

The Fraunhofer-Gesellschaft is a recognized non-profit organization named after Joseph von Fraunhofer (1787–1826), an illustrious researcher, inventor and entrepreneur hailing from Munich.

Customers and contractual partners are:

- Industry
- Service sector
- Public administration

Key figures at a glance

- 76 institutes and research units
- 30,800 staff
- 3.0 billion euros annual research budget totaling
- About two-thirds 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

The Fraunhofer-Gesellschaft is the leading organization for applied research. Since 1949, it has been our mission to strengthen the competitiveness of the German and European economies and their regional research and innovation.

Concentrating on future-relevant key technologies and transferring our ideas and research findings to industry, business and society, we are helping shape German and European innovation.«

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

- Organic Electronics, Electron Beam and Plasma Technology FEP
  www.fep.fraunhofer.de
- Laser Technology ILT
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- Applied Optics and Precision Engineering IOF
  www.iof.fraunhofer.de
- Physical Measurement Techniques IPM
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- Surface Engineering and Thin Films IST
  www.ist.fraunhofer.de (associated)
- Telecommunications, Heinrich Hertz Institute HHI
  www.hhi.fraunhofer.de (associated)
- Optronics, System Technologies and Image Exploitation IOSB
  www.iosb.fraunhofer.de (associated)

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.

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

Central Office

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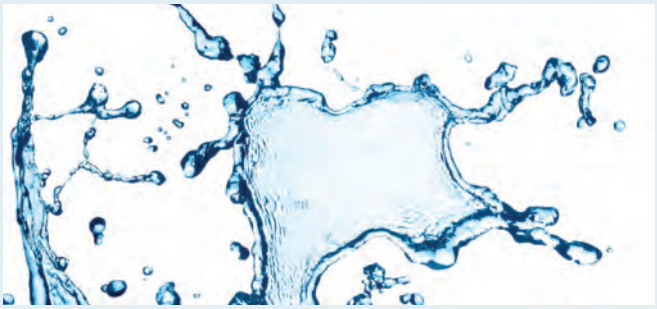
Fraunhofer-Business Area Cleaning

The Fraunhofer-Business Area Cleaning combines the expertise of 9 different Fraunhofer Institutes in the field of industrial surface cleaning and thus offers a very broad spectrum of technological competence and industry relevance. With its own website, regular newsletters and social media activities, and as a specialist partner of the leading international trade fair parts2clean, it achieves a wide international reach.

The Fraunhofer-Business Area Cleaning makes a decisive contribution to the development and industrial use of cleaning technologies. Small and medium-sized companies in particular, but also large companies, receive competent support. They benefit from the comprehensive expertise in the field of analytical and experimental development of cleaning methods and processes as well as analytical methods and procedures for process monitoring and quality assurance.
Various further training formats, from special seminars at individual member institutes to IHK (chamber of industry and commerce)-certified advanced qualifications, are an essential, complementary pillar of knowledge transfer.

The office is currently located at the Fraunhofer FEP.
Frank-Holm Rögner is the elected spokesperson.



THE CLEANING EXPERTS

Central Office

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

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The Fraunhofer-Business Area Cleaning looked back on a successful 20 years in 2023.

Where there is planing, there are chips – true to this proverb, almost every manufacturing or processing company is aware of the relevance of cleaning processes and the influence of contamination on product quality. In the 2000s, the question of expertise in the field of surface cleaning also arose within the Fraunhofer-Gesellschaft. This was the reason and motivation for the birth of the then Fraunhofer Cleaning Technology Alliance on December 5, 2002. Today active as a Fraunhofer Business Area, this network unites the industrial cleaning activities of the Fraunhofer Institutes FEP, IGB, IGCV, IPA, IPK, IPM, IST, IVV-DD and IWS.

A key activity of the alliance in its first year was the joint planning and successful launch of parts2clean, which was newly established in 2003. In particular, the accompanying specialist forum at this leading international trade fair has been a visitor magnet from the very beginning and is currently the largest international specialist event in this field. The specialist forum is currently organized and moderated by the Fraunhofer-Business Area Cleaning in cooperation with the German Industrial Parts Cleaning Association (FiT).

Innovative trends and developments from the member institutes often make it possible to overcome new industrial challenges. Traditionally, the Fraunhofer FEP plasma cleaning processes as well as electron beam processes for sterilization – the high-end of cleaning processes – play a key role for the Fraunhofer FEP.

Memberships

- AK Glasig-kristalline Multifunktionswerkstoffe
  www.ak-gkm.bam.de
- AMA Fachverband für Sensorik e. V.
  www.ama-sensorik.de
- biosaxony e. V.
  www.biosaxony.com
- Bundesverband Der Mittelstand BVMW e. V.
  www.bvmw.de
- Deutsche Gesellschaft für angewandte Optik
  www.dgao.de
- Deutsche Glastechnische Gesellschaft
  www.hvg-dgg.de/home/dgg.html
- Deutscher Industrie-Reinigungs-Verband
  www.dirv.org
- Deutsches Flachdisplay Forum e. V.
  www.displayforum.de
- Dresden-concept e. V.
  www.dresden-concept.de
- Energy Saxony e. V.
  www.energy-saxony.net
- EPIC European Photonics Industry Consortium
  www.epic-assoc.com
- European Sustainable Nanotechnology solutions Association
  www.esna-assoc.eu
- Europäische Forschungsgesellschaft Dünne Schichten e. V.
  www.efds.org
- Fachverband für Mikrotechnik IVAM
  www.ivam.de
- Forschungsallianz Kulturerbe
  www.forschungsallianz-kulturerbe.de
- Forum MedTech Pharma
  www.medtech-pharma.de
- Fraunhofer Geschäftsbereich Reinigung
  www.reinigung.fraunhofer.de
- Fraunhofer-Allianz autoMOBILproduktion
  www.automobil.fraunhofer.de
- Fraunhofer-Allianz Batterien
  www.batterien.fraunhofer.de
- Fraunhofer-Verbund Light & Surfaces
  www.light-and-surfaces.fraunhofer.de
- Fraunhofer-Verbund Mikroelektronik
  www.mikroelektronik.fraunhofer.de
- Fraunhofer-Wasserstoff-Netzwerk
  www.wasserstoff.fraunhofer.de
- FutureSax Sächsisches Transfernetzwerk
  www.futuresax.de/transfer/saechsisches-transfernetzwerk
- HZwo e. V.
  www.hzwo.eu
- Informationsdienst Wissenschaft
  www.idw-online.de
- Innovationsnetzwerk CleanHand
  www.cleanhand.de
- Innovationsnetzwerk DekubiTel
  www.dekubiPhonede
- International Council for Coatings on Glass ICCG e. V.
  www.iccg.eu
- International Electrotechnical Commission IEC, TC 110, WG 12
  www.iec.ch
- International Irradiation Association
  www.iiaglobal.com
- KIC CCI – ICE-Konsortium Innovation by Creative Economy
- Kompetenznetz Industrielle Plasma-Oberflächentechnik e. V.
  www.inplas.de
- Kompetenznetz Plasma Germany
  www.plasma-germany.org
- Kompetenzzentrum Luft- und Raumfahrttechnik Sa/Thü e. V. LRT
  www.lrt-sachsen-thueringen.de
- MicroLED Industry Association
  www.microledassociation.com
- MIPI Alliance
  www.mipi.org
- Netzwerk »Dresden – Stadt der Wissenschaften«
  www.dresden.de
- Organic and Printed Electronics Association
  www.oe-a.org
- R2RNet
  www.r2r-net.eu
- SenSa Sensorik Sachsen
  www.sensorik-sachsen.de
- Silicon Saxony e. V.
  www.silicon-saxony.de
- Smart³ materials – solutions – growth
  www.smarthoch3.de
- Society for Information Display
  www.sid.org
- Space2Health
  www.space2health.eu
- SPIE International Society for Optics and Photonics
  www.spie.org
- VDE Verband der Elektrotechnik – Bezirksverein Dresden e. V.
  www.vde-dresden.de
- VDE Verband der Elektrotechnik – DKE-Liste »Fachkreise«
  www.vde.com
- VDMA Organic Electronics Association (OE-A)
  www.oe-a.org
- Verband Deutsches Reisemanagement e. V. (VDR)
  www.vdr-service.de/der-verband/der-vdr

Theses

Diploma Theses

Author	Title	University
H. Kunert	Untersuchungen zum Einfluss einer Plasmavorbehandlung von Kunststofffolien mittels Linearer Ionen Quelle (LIS) im Rolle-zu-Rolle-Prozess	TU Dresden
P. Engelmann	Designarchitektur und Entwurfstechniken zur Realisierung eines SOCs mit einer Chipgröße größer als das Bildfeld am Beispiel eines Mikrodisplay-Chips	TU Dresden

Master Theses

Author	Title	University
R. Ganesan	Neural Networks for the Analysis of Image Data in OLED Microdisplay Manufacturing	TU Darmstadt
L. Kähne	Biobasierte Materialentwicklung mittels Nanocellulosen unter Nutzung der niederenergetischen Elektronenstrahltechnologie	TU Dresden (IHI Zittau)
D. Ullrich	Evaluierung neuer Flüssigdosimeter für die niederenergetische Elektronenstrahltechnologie	HTW Dresden
C. Thon	Konzeptionierung und Untersuchungen zu einer kompakten Low-Power Datenbrille mit OLED-Mikrodisplay	HTW Dresden
L. Bayer	Untersuchung der mechanischen Kennwerte strahlenvernetzter polymerer Verbundwerkstoffe mit hohem Füllgrad für den Einsatz als Bipolarplatte in Brennstoffzellen	Hochschule für Angewandte Wissenschaften Hof

Publications

Authors	Title	Place of publication
A. Zukauskaite	Piezoelectric Aluminium Scandium Nitride (AlScN) Thin Films: Material Development and Applications in Microdevices	Special Issue Reprint micromachines, 2023, ISBN 978-3-0365-6376-1
A. Zukauskaite, S. Barth	Nitrides for Piezoelectric Energy Harvesting	Journal of Physics and Materials, Vol. 6, Kapitel 3.4 in Roadmapp on Energy Harvesting Materials, 2023, p. 63-67
S. Saager, L. Decker, T. Kopte, B. Scheffel, B. Zimmermann	High-Performance Anodes Made of Metallic Lithium Layers and Lithiated Silicon Layers Prepared by Vacuum Technologies	batteries, Vol. 9, Issue 2, 2023, Artikel 75
T. Tulus, J. Wang, Y. Galgan, E. von Hauff	Quantifying electrochemical losses in perovskite solar cells	Journal of Materials Chemistry C, Open Access, 2023, p. 1-10
C. Dittfeld, C. Welzel, U. König, A. Jannasch, K. Alexiou, E. Blum, S. Bronder, C. Sperling, M. F. Maitz, S.-M. Tugtekin	Hemocompatibility tuning of an innovative glutaraldehyde-free preparation strategy using riboflavin/UV crosslinking and electron irradiation of bovine pericardium for cardiac substitutes	Biomaterials Advances, Vol. 147, 2023, Artikel 213328
M. Fahland, C. Steiner, M. Schott	Dünnschichttechnologien für die Energiewende	Galvanotechnik, Heft 1, 2023, S. 33-36
N. Gürtler, U. König	Antifouling-Beschichtungen per Elektronenstrahl	Journal für Oberflächentechnik JOT, Vol. 63, Nr. 2, 2023, S. 14-15
M. Ghazijahani, C. Kästner, V. Valori, A. Thieme, K. Täschner, J. Schumacher, C. Cierpka	The SCALEX facility – an apparatus for scaled fluid dynamical experiments	tm-Technisches Messen, Band 90, 2023, p. 1-14
S. Ghosh, A. Hinz, M. Frentrup, S. Alam, D. Wallis, R. Oliver	Design of step-graded AlGaN buffers for GaN-on-Si heterostructures grown by MOCVD	Semiconductor Science and Technology, Vol. 38, Issue 4, 2023, Artikel 044001
T. Teichmann, L. Dincklage, L. Schaap, D. Schreuder, R. Blüthner, F. Winckler, S. Schopf, U. König, B. Zimmermann, G. Mattausch	Advances in Electron Beam Technology for Environmental and Biotechnological Applications at Fraunhofer FEP	Journal of Physics: Conference Series, Nr. 2443, 2023, Artikel 012017, 14th International Conference on Electron Beam Technologies, Varna, Bulgarien, 26. Juni-01. Juli 2022, EBT Konferenz 2022
S. Rettenberger, P. Landstorfer, G. Herl, B. Meyer, G. Mattausch, R. Labitzke	Multi-Source-CT for inline inspection of extruded profiles	e-Journal of Nondestructive Testing, eJNDT, Vol. 28, Issue 3, 2023, 9 pages, 12th Conference on Industrial Computed Tomography, iCT 2023, Fürth, Germany, 27. Februar-03. März 2023
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N. A. Morrison, M. Campo, T. Crouch, R. Verghese, S. Straach	High-performance AlOx thin films for next generation sustainable packaging	Converting Quarterly, Vol. 1, 2023, p. 57-62
M. Fahland, J. Szelwicka, W. Langgemach	Energy-saving potential of thermochromic coatings in transparent building envelope components	Journal of Facade Design and Engineering, Vol. 11 No. 2 (2023): Special Issue Multifunctional Façades for Renovation through Industrialization, p. 197–210

Authors	Title	Place of publication
P. Wartenberg, B. Richter, S. Brenner, J. Baumgarten, S. Lenk, K. Fehse, D. Schlebusch, M. Törker, A. Fritscher, J. Zeltner, C. Schmidt, M. Rolle, S. Damnik, J. Mütze, F. Schuster, U. Vogel	Organic-on-silicon photonic platform for advanced imagers, microdisplays and sensors	SPIE Proceedings Volume 12425, Smart Photonic and Optoelectronic Integrated Circuits 2023, Artikel 124250E, SPIE Photonic West-Smart Photonic and Optoelectronic, 2023, San Francisco, USA, 31. Januar-02. Februar 2023
M. Fahland	Photoinduziert hydrophile Schichten von der Rolle	Journal für Oberflächentechnik JOT, Vol. 63, Nr. 4, 2023, S. 16-17
J.-P. Heinß, L. Klose	High-Rate Sputter Etching of Substrates Using Hollow-Cathode Arc Discharge Sources	SVC Bulletin, Spring 2023, p. 66-75
D. Q. Tran, F. Tasnadi, A. Zukauskaite, J. Birch, V. Darakchieva, P. P. Paskov	Thermal conductivity of $Sc_xAl_{1-x}N$ and $Y_xAl_{1-x}N$ alloys	Applied Physic Letters, Vol. 122, Issue 18, 2023, Artikel 182107
M. Bolognesi, M. Prosa, M. Törker, L. Lopez Sanchez, M. Wieczorek, C. Giacomelli, E. Benvenuti, P. Pellacani, A. Elferink, A. Morschhauser, L. Sola, F. Damin, M. Chiari, M. Whatton, E. Haenni, D. Kallweit, F. Marabelli, J. Peters, S. Toffanin	A Fully Integrated Miniaturized Optical Biosensor for Fast and Multiplexing Plasmonic Detection of High- and Low-Molecular-Weight Analytes	Advanced Materials, Vol. 35, 2023, Artikel 2208719z, p. 1-13
J.-P. Heinß	Vacuum Deposition of Aluminum Alloys with 1 µm/s on Different Types of Semi-finished Products	66th Annual Technical Conference Proceedings, SVC Technical Conference, Washington, USA, 06.-11. Mai 2023 , p. 288-300
P. Li, S. H. C. Askes, E. del Pino Rosendo, F. Ariese, C. Ramanan, E. von Hauff, A. Baldi	Nanoscale Thermometry of Plasmonic Structures via Raman Shifts in Copper Phthalocyanine	Journal of Physical Chemistry C, Vol. 127, Issue 20, 2023, p. 9690-9698
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G. Gotzmann, L. Kenner, U. König	Sterilisation von Medizinprodukten, zwischen Tradition und Innovation	meditronic-journal, Vol. 3, 2023, S. 60-62
C. Sternemann, S. Dogan-Surmeier, F. Gruber, S. Bieder, P. Schlenz, M. Paulus, C. Albers, E. Schneider, N. Thiering, C. Maurer, M. Tolan, P. Wollmann, S. Cornelius	Towards in-line real-time characterization of roll-to-roll produced ZTO/Ag/ITO thin films by hyperspectral imaging	Journal of Physics D: Applied Physics, Vol.56, Issue 36, 2023, Artikel 365102
B. Scheffel, O. Zywitzki, T. Kopte	Diamond-like films of tetrahedral amorphous carbon deposited by anodic arc evaporation of graphite	Social Science Research Network, SSRN, Juli 2023, Open Access, Artikel 4504278

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K. Pingen, S. Neuhaus, N. Wolff, L. Kienle, A.Zukauskaite, E. von Hauff, A. M. Hinz	Influence of Si(111) substrate off-cut on AlN film crystallinity grown by magnetron sputter epitaxy	Journal of Applied Physics, Vol. 134, 2023, Artikel 025304
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P. Wartenberg, B. Richter, S. Brenner, J. Zeltner, C. Schmidt, J. Baumgarten, A. Fritscher, S. Lenk, M. Rolle, M. Törker, U. Vogel	High-brightness OLED-on-silicon on semitransparent CMOS backplane for advanced near-to-eye microdisplays	SPIE. Digital Library, Proceedings Volume 12624, Digital Optical Technologies, 2023
W. Langgemach, G. Lorenz, K. Täschner, J. Neidhardt	Optische Schichten und ihr Einfluss auf die Belastbarkeit flexibler Gläser	Vakuum in Forschung und Praxis, Vol. 35, Issue 4, 2023, p. 28-33
U. Hartung, D. Glöß, J. Neidhardt, A. Drescher, H. Sahm, P. Büttner	Slim Backlights for Holographic 3D Displays by Advanced Coatings Capabilities	SID Diggest of Techn. Papers, Vol. 54, Issue 1, 2023, p. 245-247, Proceedings Display Week 2023, Los Angeles, USA, 21.-26. May 2023
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V. Eberlein, M. Ahrends, L. Bayer, J. Finkensieper, J. K. Besecke, Y. Mansuroglu, B. Standfest, F. Lange, S. Schopf, M. Thoma, J. Dressman, C. Hesse, S. Ulbert, T. Grunwald	Mucosal Application of a Low-Energy Electron Inactivated Respiratory Syncytial Virus Vaccine Shows Protective Efficacy in an Animal Model	Viruses, Vol.15, Issue 9, Artikel 1846, 2023, Open Access
L. Krauss, R. Schab, S. Unz, M. Michael, M. Krug, J. Puettmann, H. Nizard, D. Glöß	Investigation of the Chemical Durability and Thermal Impact on Functional Coated Surfaces	Heat Transfer Engineering, 2023, Open Access
S. Vogel, K. Täschner, M. Schlegers, S. Weyer	Multi-Sensor-integrierte adaptive Scheinwerfer für robuste Fahrerassistenzsysteme	ATZ elektronik, Vol. 18, Ausgabe 10, 2023, S. 16-22
F.-H. Rögner	20 Jahre aktiv für die industrielle Teilereinigung	Journal für Oberflächentechnik JOT, Vol. 63, Nr. 11, 2023, S. 14-15
I. Schedwill	Prozessoptimierung während der Rolle-zu-Rolle-Beschichtung	Journal für Oberflächentechnik JOT, Vol. 63, Nr. 11, 2023, S. 40-41
K. Fehse, M. Törker, D. Schlebusch, S. Brenner, J. Baumgarten, M. Rolle, P. Wartenberg, B. Richter, U. Vogel	Combination of organic and inorganic semiconductor for sensing applications	IEEE Sensors, 2023, Open Access, p. 1-4
K. Pingen, A. M. Hinz, P. Sandström, N. Wolff, L. Kienle, L. Scipioni, J. Greer, E. von Hauff, L. Hultman, J. Birch, C.-L. Hsiao	High growth rate magnetron sputter epitaxy of GaN using a solid Ga target	Vacuum, 2023, Article 112852
M. Törker	Innovative Sensorik für Lebensmittelsicherheit und Qualität	Lebensmittelbrief, Ausgabe Nov./ Dez. 2023, S. 26-27
R. Wang, S. Hasanefendic, E. v. Hauff, B. Bossink	A System Dynamics Approach to Technological Learning Impact for the Cost Estimation of Solar Photovoltaics	energies, Vol. 16, Nr. 24, 2023, Artikel 8005, p. 1-17

Protective Rights

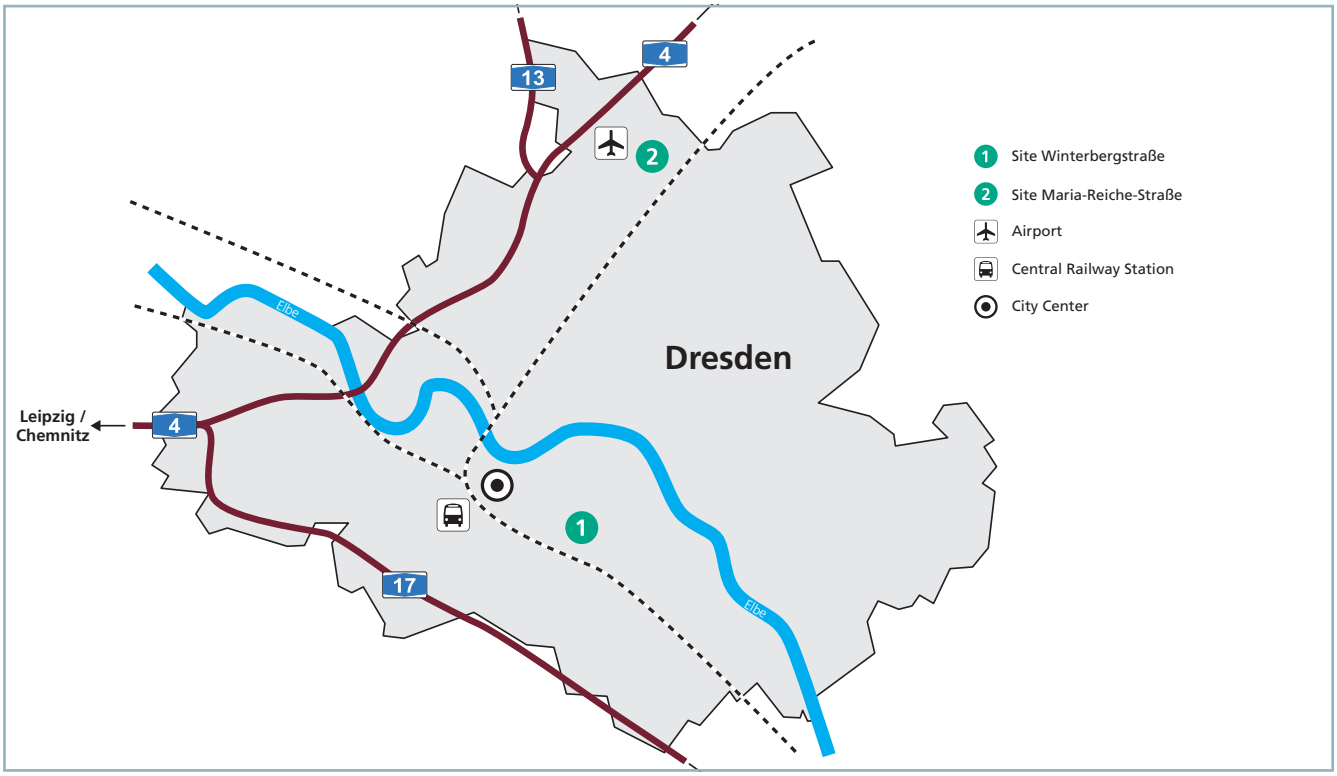
Patent number	Title	Inventor(s)	Registration	Grant
DE 10 2014 110 835 B1	Vorrichtung zum Bedampfen eines Substrates innerhalb einer Vakuumkammer	B. Scheffel, C. Metzner, H. Morgner, B. Finkenwirth, F. Händel	31.07.2017	05.01.2023
DE 10 2021 127 146 B3	Vorrichtung zum Beaufschlagen von Schüttgut mit beschleunigten Elektronen	G. Mattausch, R. Blüthner, H. Flaske, V. Kirchhoff, J. Kubusch	19.10.2021	23.02.2023
TW 1794249 B	Multi-Layer Functional Film and Production Method thereof	J. Fahlteich, N. Prager, M. Fahland, O. Zywitzki, V. von Morgen, R. Eveson	27.06.2018	01.03.2023
DE 10 2021 127 147 B3	Vorrichtung zum Beaufschlagen von Schüttgut mit beschleunigten Elektronen	G. Mattausch, R. Blüthner, H. Flaske, J. Kubusch, L. Dincklage, F. Winckler, T. Schumpa	19.10.2021	02.03.2023
DE 10 2021 111 097 B4	Hohlkathodensystem zum Erzeugen eines Plasmas und Verfahren zum Betreiben eines solchen Hohlkathodensystems	G. Mattausch, B. Meyer, H. Flaske, V. Kirchhoff, S. Weiss, R. Labitzke, B. Zimmermann, J. Kubusch	29.04.2021	06.04.2023
KR 10-2520785 B1	Method for Adjusting the Emission of an OLED	E. Bodenstein, C. Metzner, U. Vogel, M. Schober, S. Saager	17.08.2018	07.04.2023
CN 112789060 B	Method for Inactivating Biologically Active Components in a Liquid	A. Weidauer, G. Gotzmann, V. Kirchhoff, J. Kubusch, C. Wetzel, J. Schönfelder	01.04.2021	07.02.2023
KR 10 2568659 B1	Multi-Layer Functional Film and Production Method thereof	J. Fahlteich, N. Prager, M. Fahland, O. Zywitzki, V. von Morgen, R. Eveson	26.06.2018	22.08.2023
DE 10 2021 130 776 B4	Vorrichtung und Verfahren zur Behandlung von Flüssigkeit	T. Martin, J. Casado-Portillo, F.-H. Rögner, A. Poremba	24.11.2021	07.09.2023
CN 110997321 B	Multi-Layer Functional Film and Production Method thereof	J. Fahlteich, N. Prager, M. Fahland, O. Zywitzki, V. von Morgen, R. Eveson	26.06.2018	01.09.2023
US 11,802,271 B2	Method for Irradiation mammalian Cells with Electron Beam and/or X-Rays	F.-H. Rögner, S. Ulbert, J. Burkhardt, J. Portillo, J. Schönfelder	16.09.2019	31.10.2023
EP 3 924 307 B1	Method for Increasing the Strength of a Glass Substrate	M. Junghähnel, J. Westphalen, T. Preussner, W. Walther	13.02.2020	06.12.2023
US 11,839,484 B2	Method and Device for the objective Determination of Capillary Refill Behavior on a Human Body Surface	U. Vogel, B. Richter, T. Richter	28.05.2021	12.12.2023

Our locations

Institute Center Dresden, Fraunhofer FEP Technology Center, Winterbergstraße

Research Center »Resource-Efficient Energy Technologies« (RESET), Winterbergstraße

Institute Center Dresden-Klotzsche, Maria-Reiche-Straße



Highlights

HZwo workshop »Surface functionalization for hydrogen applications«

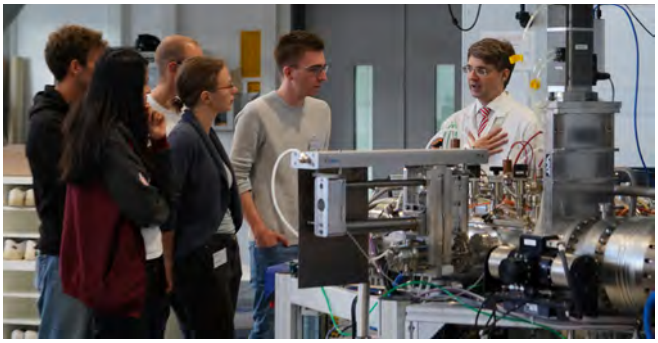
Project meeting »CUSTOM»

Basic seminar on cleaning

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

Alumni spring meeting

Joint project »secureAR« wins Technology Award



Photonica Summer School

Strategy audit at the Fraunhofer FEP

Trade fair participations

CES® Consumer Electronics Show

Las Vegas, USA
05.01. – 08.01.2023

Medtec Live

Nuremberg, Germany
23.05. – 25.05.2023

SPIE. AR|VR|MR

San Francisco, USA
31.01. – 02.02.2023

V 2023

Dresden, Germany
19.09. – 21.09.2023

SPIE. Photonics West

San Francisco, USA
31.01. – 02.02.2023

parts2clean

Stuttgart, Germany
26.09. – 28.09.2023

embedded world

Nuremberg, Germany
14.03. – 16.03.2023

Clean Hydrogen Convention

Dresden, Germany
25.10. – 26.10.2023

BAU 2023

Munich, Germany
17.04. – 22.04.2023

IEEE Sensors

Vienna, Austria
29.10. – 01.11.2023

66th Annual SVC TechCon

Washington D.C., USA
08.05. – 11.05.2023

European Hydrogen Week

Brussels, Belgium
20.11. – 24.11.2023

SID Display Week

Los Angeles, USA

23.05. – 25.05.2023

W3+ Fair Convention

Jena, Germany

29.11. – 30.11.2023

Imprint

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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 and optical filters.

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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