Fraunhofer
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Fraunhofer Institute for Surface Engineering and Thin Films IST

Annual Report 2023

Fraunhofer IST Annual Report

2023

With our methods, tools and technologies, we carry out work on the sustainability-oriented planning and design of factory systems. We thereby take into account the dynamic interactions between production machines and process chains, technical building equipment and the building envelope."

Prof. Dr.-Ing. Christoph Herrmann, Institute Director

Foreword

Prof. Dr.-Ing. Sabrina Zellmer and Prof. Dr.-Ing. Christoph Herrmann.

Ladies and Gentlemen,

2023 was a very dynamic year for the Fraunhofer IST, and brought with it a number of changes and further developments. Last year, we bid farewell to Dr. Lothar Schäfer, who retired as Deputy Director of the institute. On 1st July 2023, Prof. Dr.-Ing. Sabrina Zellmer, Head of the department "Process Technology and Production Engineering for Sustainable Energy Storage Systems" and Professor for "Battery and Fuel Cell Process Technology" at the Institute for Particle Technology (iPAT) at the TU Braunschweig, took over this position.

Furthermore, sustainability expert Prof. Dr. Stephan Krinke has been working with us at the Fraunhofer IST since 2023 and is establishing a new "Sustainability Management and Life Cycle Engineering" department. With this step, we not only want to make a cross-industry contribution towards greater sustainability in production, but to also accommodate the increasing demand in this field.

In 2023, we were also able to further expand our activities in the area of battery and hydrogen technologies in close cooperation with the Technische Universität Braunschweig. A further focus is formed by holistic solutions in line with sustainability for mobility at our location in Wolfsburg.

With this in mind, we have, in collaboration with the TU Braunschweig and local partners, strategically further developed the Open Hybrid LabFactory in Wolfsburg. The Fraunhofer Center Circular Economy for Mobility CCEM based there is under the leadership of Prof. Michael Thomas from the Fraunhofer IST.

The aforementioned developments and many other exciting projects would not be possible without the commitment and expertise of our employees or, indeed, without our partners from the worlds of politics, business and science.

We would like to express our sincere thanks to all of them for their trusting cooperation. We hope that all our readers enjoy this Annual Report, and we look forward to receiving your feedback and ideas for future collaborations.

With very best regards,

Prof. Dr.-Ing. Christoph Herrmann
Institute Director

Prof. Dr.-Ing. Sabrina Zellmer
Deputy Institute Director

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2023

Our Board of Trustees

Interface between research and practice

Our illustrious Board of Trustees is comprised of representatives from science, business and public life. The members of our Board of Trustees provide us with advice and support on issues relating to our professional orientation and structural changes, and endow our institute with important impetus. Within the framework of this year's meeting of the Board of Trustees, which took place for the first time at the Wasserstoff Campus Salzgitter on the premises of Robert Bosch Elektronik GmbH, three new members were welcomed: Dr.-Ing. Marko Gernuks, Dr. Wolfgang Müssel and Uwe Heydenreich.

Chairman
Dr. Philipp Lichtenauer / Plasmawerk Hamburg GmbH

Prof. Dr. Peter Awakowicz / Ruhr-Universität Bochum

Dr. med. Thomas Bartkiewicz /
Städtisches Klinikum Braunschweig gGmbH

Frank Benner / B + T Technologies GmbH

Claudia Martina Buhl / VDI/VDE Innovation + Technik GmbH

Dr.-Ing. Marko Gernuks / Volkswagen AG

Uwe Heydenreich / TRUMPF Hüttinger GmbH + Co. KG

Prof. Dr. Tim Hosenfeldt /
Schaeffler Technologies AG & Co. KG

Dr. Sebastian Huster /
Niedersächsisches Ministerium für Wissenschaft und Kultur

Prof. Dr. Angela Ittel / Technische Universität Braunschweig

Hon.-Prof. Dr.-Ing. Michael Juhnke /
F. Hoffmann-La Roche AG

Prof. Dr. Simone Kauffeld /
Technische Universität Braunschweig

Prof. Dr.-Ing. Frank Kleine-Jäger / BASF SE

Cordula Miosga /
Arbeitgeberverband Region Braunschweig e. V.

Wolfgang Müssel /
Bundesministerium für Bildung und Forschung

Dr.-Ing. Stefan Rinck / Singulus Technologies AG

Dr. Joachim Schulz / Verband der Metall- und Elektroindustrie Baden-Württemberg e. V. (Südwestmetall)

Dr. Jutta Trube / Verband Deutscher Maschinen- und Anlagenbau e. V.

Dr. Kai U. Ziegler / Eagle Burgmann Germany GmbH & Co. KG

Excellent Collaboration

An interview with Pia von Ardenne, CEO of VON ARDENNE group

What are the current challenges for your industry and what contribution is provided by the Fraunhofer IST in this context?

The requirements regarding coatings in precision optics must increasingly keep pace with those of the semiconductor industry. The reason for this is the trend towards opto-electronic coatings, i. e. the combination of optics and semiconductors. In order to meet these requirements, the coatings must not have any impurities or defects and the production environment must be designed in accordance with clean-room standards.

The Fraunhofer IST has a laboratory at semiconductor level. It offers us the best possibilities for sampling and is therefore an important addition to the facilities in our own Technology Application Center. A further challenge lies in the search for sputter-capable materials for the technological alternative to the established evaporation processes. Here, the Fraunhofer IST is providing us with support in the development of a process and the implementation of the necessary tests."

1

Personal details

Pia von Ardenne is a granddaughter of the scientist, inventor and entrepreneur Manfred von Ardenne. She is the third generation of her family to successfully manage the company.

Before taking over the management of the entire VON ARDENNE Group in 2018, Ms. von Ardenne had been an active member of the management board of VON ARDENNE GmbH since 2016. In the years before that, she was a partner in the family business.

2

The company building of VON ARDENNE GmbH at the headquarters in Dresden.

Copyright: VON ARDENNE Corporate Archive (Figures 1 and 2)

You have been working in collaboration with the Fraunhofer IST since 1996. What special project stands out and distinguishes your collaboration with the IST?

Of particular note is a project that began in 2019 with a call for tenders from the Fraunhofer IST, in which a partner was being sought for the construction of a turntable coating system for optical precision coatings. Within the framework of the collaborative work on the system, an idea was developed for a system that can coat substrates from both sides simultaneously. This offers a significant advantage, particularly for transmission optics such as lenses or filters. As a result of VON ARDENNE being awarded the contract in November 2019, the world's first system of this kind was created. It enables the Fraunhofer IST to realize optical precision coatings on 2D and 3D components up to 70 mm in height. Since the installation of the system in Braunschweig, both sides have benefited. The Fraunhofer IST has the most advanced system on the market and can utilize it to realize even the most unusual industrial orders. And, as a customer, VON ARDENNE can use the system in the Fraunhofer IST laboratory and benefits thereby from the institute's optical monitoring system."

What plans do you have – also with regard to the Fraunhofer IST – for the future?

The Fraunhofer IST is a partner in the Center for Energy Storage and Systems ZESS in Braunschweig and is involved in the Wasserstoff Campus Salzgitter e. V. At the Fraunhofer ZESS, researchers are working on the development and production of future energy storage systems with a particular focus on process engineering, the associated factory systems and Life Cycle Management. At the Wasserstoff Campus, the Fraunhofer IST provides support for, amongst other things, the technological development of materials and processes for electrolyzers, storage systems and fuel cells.

The VON ARDENNE systems can serve both topics. As a result, further connecting factors exist for collaborative projects, and initial contacts have already been made in the field of Life Cycle Engineering."

The VON ARDENNE group

VON ARDENNE is a pioneer in the development and production of vacuum coating systems. Areas of application include the exploitation of renewable energies, mobility applications, and the manufacture of sustainable products.

As a globally active family business, the Group is addressing the social and ecological challenges of our time. The technological solutions in vacuum coating enable customers from all over the world to manufacture ecologically valuable products in an economically sustainable way. VON ARDENNE is represented at seven locations in Europe, Asia and North America. More than 1000 of the company's systems are in use in more than 50 countries worldwide.

Further information: vonardenne.de

3

The Fraunhofer IST / VON ARDENNE team in front of the OPTA X turntable coating system in the precision-optics laboratory at the institute in Braunschweig (from left to right, back: Dr. Michael Vergöhl, Dr. Philipp Farr, Carola Brand, Pia von Ardenne, Prof. Dr.-Ing. Christoph Herrmann; from left to right, front: Michael Schneider, Torsten Winkler).

Institute profile

As an innovative and internationally recognized partner for research and development, the Fraunhofer Institute for Surface Engineering and Thin Films IST develops future-oriented products – including the associated competitive and scalable production systems.

Our research encompasses plant engineering, entire process chains of process engineering, process technology and manufacturing technology all the way through to the consideration of entire factories. Taking the requirements of sustainability as a starting point, we maintain an overview of the entire product life cycle – from the material, through the process of creating the component and product, and on to recycling.

Tailor-made and sustainable: Our sector-based solutions

In interdisciplinary teams and based on our technology and competence fields, we offer our customers from industry and research customized solutions that fulfill the requirements for sustainability for various sectors, e. g. plant and mechanical engineering, tools, vehicle construction, aerospace, energy, optics, medical and pharmaceutical process engineering, environmental technology, chemistry, and the digital economy.

Drawing on a broad spectrum of expertise, technologies, processes and coating materials, we design the optimum process chain for the respective task, right through to the digital design of the entire factory.

Further core competencies of the Fraunhofer IST are:

- Energy storage systems with focus on battery cell production and hydrogen technology
- Micro and sensor technology / Industry 4.0
- Tribological systems
- Precision optical coatings
- Multifunctional surfaces for medical technology and pharmaceutical production
- Flexible production systems
- Cyber-physical systems and computational surface engineering & science
- Sustainability management and life cycle engineering

We apply our expertise in a diverse range of technologies for the coating, treatment and structuring of surfaces and the design of the associated production systems. These include:

- Electrochemical processes, in particular electroplating
- Atmospheric pressure processes
- Low-pressure plasma processes with the main focus on magnetron sputtering, highly ionized plasmas and plasma-activated vapor deposition (PECVD)
- Chemical vapor deposition with the main focus on hot-wire CVD
- Atomic layer deposition (ALD)
- Chemical, mechanical and thermal surface treatment

Furthermore, the Fraunhofer IST is very well equipped as regards surface analytics and has accrued many years of expertise in quality assurance. Added to this is extensive experience in the modeling and simulation of both product properties and the associated processes as well as production and factory systems. For the systematic consideration of sustainability requirements, the Fraunhofer IST offers extensive expertise in quantitative sustainability assessment and a circular economy using Life Cycle Engineering.

The range of services offered by the Fraunhofer IST is complemented in particular by the other member institutes and facilities of the Fraunhofer Group for Production. The Group pools the expertise of the Fraunhofer-Gesellschaft for the "production of the future" and elaborates innovative system solutions along the entire value chain.

Within the framework of direct contract research, the Fraunhofer IST offers its customers not only the licensing of software, patents and expertise but also consulting and innovation management, customized further-training programs, and services in the fields of process development and equipment and plant engineering. Alongside direct contract research, we work together with partners from industry and science in publicly funded projects. In addition to application-oriented research, the staff of the Fraunhofer IST also carry out the associated fundamental scientific work in cooperation with universities and non-university research institutes.

For the Fraunhofer IST as well as for the Fraunhofer institutes as a whole, it is a matter of principle to always interact closely with the local universities. For the institute, with its headquarters in Braunschweig and regional locations in Wolfsburg and Salzgitter, the Technische Universität Braunschweig is, correspondingly, a central cooperation partner. The TU institutes directly associated with the Fraunhofer IST include: Institute of Machine Tools and Production Technology (IWF), Institute for Surface Technology (IOT), and the Institute for Particle Technology (iPAT).

Where to find us – our locations

1

Fraunhofer Institute for Surface Engineering and Thin Films IST

Main location

Address:
Riedenkamp 2
38108 Braunschweig, Germany

Office premises: 2,000 m²
Laboratory premises: 5,500 m²

Contact:
info@ist.fraunhofer.de
Phone +49 531 2155-0

Focus areas:
Thematic focuses at our main location encompass the areas of tribology, sensor technology, optics, diamond technology and medical technology as well as sustainability management, simulation, analytics and testing technology.

2

Fraunhofer Center for Energy Storage and Systems ZESS

Address:
Lilienthalplatz 1
38108 Braunschweig, Germany

Office premises*: 400 m²
Laboratory premises*: 250 m²

*Upon completion of the new research building, a total area of approx. 3400 m² will be available.

Contact:
Dr.-Ing. Sebastian Melzig
sebastian.melzig@ist.fraunhofer.de
Phone +49 531 2155-795

Nikolas Dilger M.Sc.
nikolas.dilger@ist.fraunhofer.de
Phone +49 531 2155-660

Focus areas:
At the Fraunhofer Center for Energy Storage and Systems ZESS, we develop sustainable energy storage systems and advance them to market maturity. Our research focuses on lithium solid-state batteries, stationary storage systems, hydrogen technologies and inspection technologies. We examine the entire life cycle of energy storage systems – from raw materials through various production steps and use to recycling, thereby taking technical, economic and ecological aspects into consideration.

Energy storage

Hydrogen

3

Wasserstoff Campus Salzgitter e.V.

Address:
on the premises of
Robert Bosch Elektronik GmbH
John-F.-Kennedy-Straße 43 - 53
38228 Salzgitter, Germany

Office premises: 320 m²
Laboratory premises: 1,580 m²

Contact:
Christoph Imdahl M.Sc.
christoph.imdahl@ist.fraunhofer.de
Phone +49 531 2155-669

Focus areas:
At the Wasserstoff Campus Salzgitter e.V., we conduct research into sustainable hydrogen technologies along the entire value chain. Founded by nine key players from business, science and politics, the Campus operates as a flagship project for the demonstration of a decarbonized industrial region in the hydrogen economy. Research focuses are climate-neutral sectors through the coupling of decarbonized factories and districts, closed material and product cycles, and flexible production processes. The Campus is striving towards further growth, new partnerships and research into fuel cells, electrolyzers and CO_2-neutral factories. The further training of specialists and the promotion of global partnerships are also key objectives.

Mobility

4

Fraunhofer Center Circular Economy for Mobility CCEM

Address:
c/o Open Hybrid LabFactory e.V.
Hermann-Münch-Straße 2
38440 Wolfsburg, Germany

Office premises: 350 work places
Laboratory premises: 2,800 m²
technical center of the OHLF
For OHLF e.V., Fraunhofer-Gesellschaft, TU Braunschweig and industry.

Contact:
Prof. Dr. Michael Thomas
michael.thomas@ist.fraunhofer.de
Phone +49 531 2155-525

Focus areas:
In the Fraunhofer CCEM, the Fraunhofer IST, together with the Fraunhofer institutes IFAM, IWU and WKI, pools its expertise in the research topics of automated production systems, future interior concepts, Life Cycle Engineering and sustainable product design. In collaboration with research partners, the Fraunhofer IST is working towards the goal of developing and evaluating new materials, production techniques and digital methods in an economically and ecologically sustainable manner. In order to achieve this, procedures for automated dismantling, Re-X processes such as cleaning, remanufacturing and re-use as well as sustainable surface processes along a circular process chain are utilized and the large-scale testing of these technologies is driven forward.

Circular Economy

Plasma source development

5

Application Center of the Fraunhofer IST

Address:
Von-Ossietzky-Straße 100
37085 Göttingen, Germany

Office and laboratory premises: 1,500 m²

In cooperation with the University of Applied Sciences and Arts Hildesheim/Holzminden/Göttingen.

Contact:
Prof. Dr. Wolfgang Viöl
wolfgang.vioel@ist.fraunhofer.de |
Phone +49 551 3705-218

Focus areas:
At the Göttingen location, the focus lies on the development and transfer of coatings using low-energy plasma coating processes such as cold plasma spraying and the development of plasma sources for the production of resource-conserving coatings and products. These processes are aimed at recyclability and the bioeconomy and include fields of application such as fuel-cell and battery technology, tribology and sensor technology as well as powder modification for a diverse range of applications such as 3D printing.

Cold plasma spraying

Corrosion

6

Dortmunder OberflächenCentrum DOC

Address:
Eberhardstraße 12
44145 Dortmund

Office and laboratory premises: 1,100 m²

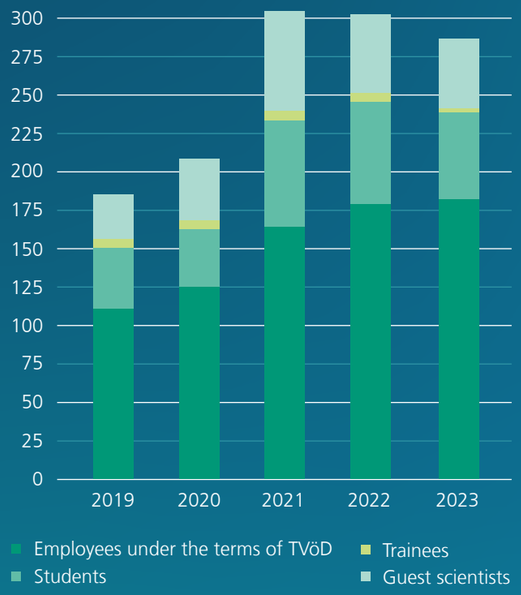
Contact:
Dipl.-Ing. Hanno Paschke
hanno.paschke@ist.fraunhofer.de
Phone +49 231 844 5453

Focus areas:
The Fraunhofer IST in Dortmund develops special PACVD hard coatings and diffusion treatments in the form of plasma nitriding or boriding for wear- and temperature-resistant surfaces. This results in surface solutions that can withstand high temperatures of over 1000 °C. Furthermore, they enable wear protection against abrasion and adhesion, e. g. for applications in hot forming. A further field of research is corrosion mechanisms that occur at high temperatures (high-temperature corrosion) or are superimposed by abrasion (tribocorrosion).

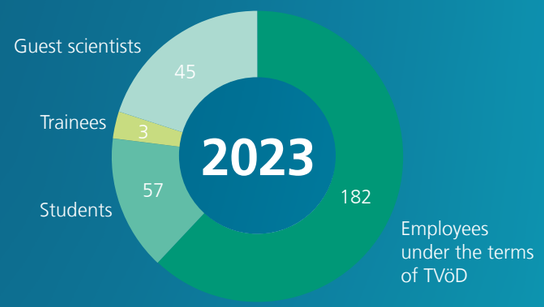
Hot forming

The institute in figures

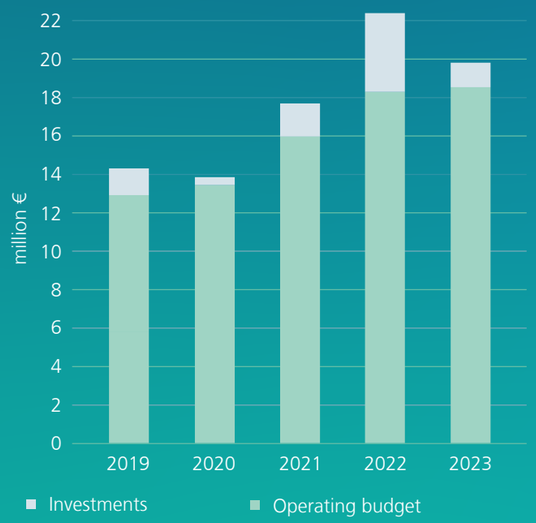
Personnel development



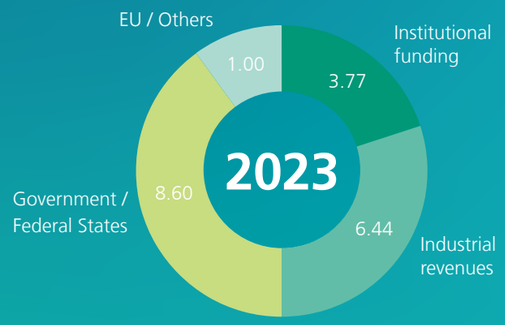
287
employees



Overall budget



€ 19.81 million
overall budget



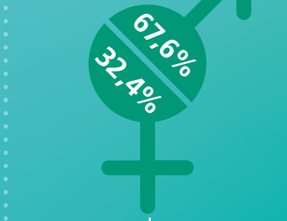
83
conference contributions

8
professorships

> 15
disciplines

7
locations

46
publications and patents



employees
under the terms of TVöD

2001*
followers

*as by Jan.8, 2024

14
nationalities

57
student assistants

4
vocational professions

Professorships

The Fraunhofer IST cooperates with numerous institutes and centers of the TU Braunschweig. Thanks to the close ties with the university, we can build our project work on the latest results from university research. The Fraunhofer IST maintains connections with the Technische Universität Braunschweig in the form of seven associated professorships. Since 2012, the institute has also been cooperating with the HAWK University of Applied Sciences and Arts Hildesheim / Holzminden / Göttingen within the framework of the Application Center in Göttingen.

Technische Universität Braunschweig

Institute of Machine Tools and Production Technology (IWF)

Prof. Dr.-Ing. Christoph Herrmann
Research foci:

- Sustainable manufacturing
- Life cycle engineering
- System of systems engineering
- Cyber-physical production systems

Prof. Dr.-Ing. Klaus Dröder
Research foci:

- Assembly / disassembly
- Process automation
- Battery and fuel cell production
- Production technologies

Prof. Dr Stephan Krinke (Honorary professorship)
Research foci:

- Sustainability management in industry
- Life-cycle engineering
- Decarbonization

Institute for Particle Technology (iPAT)

Prof. Dr.-Ing. Arno Kwade
Research foci:

- Mechanical process engineering
- Particle technology
- Battery process engineering
- Pharmaceutical and bioprocess engineering
- Powder and suspension processes

Prof. Dr.-Ing. Sabrina Zellmer
Research foci:

- Sustainable energy storage
- Material and process development for novel batteries
- Hydrogen economy and hydrogen technologies
- Sustainable factory systems and life-cycle assessment

Institute for Surface Technology (IOT)

Prof. Dr. Günter Bräuer
Research foci:

- Thin-film and surface technology
- Low-pressure plasmas
- Magnetron sputtering
- Plasma diffusion processes

Prof. Dr. Michael Thomas (Honorary professorship)
Research foci:

- Interfacial chemistry
- Atmospheric pressure plasma processes

University of Applied Sciences and Arts Hildesheim / Holzminden / Göttingen HAWK

Faculty of Engineering and Health

Prof. apl. Prof. Dr. Wolfgang Viöl
Research foci:

- Laser technology
- Plasma technology
- Plasma medicine

Your contact persons

Institute management, administration and central services

Institute management
Director
Prof. Dr.-Ing. Christoph Herrmann 1
Phone +49 531 2155-503
christoph.herrmann@ist.fraunhofer.de

Deputy Director
Prof. Dr.-Ing. Sabrina Zellmer 2
Phone +49 531 2155-528
sabrina.zellmer@ist.fraunhofer.de

Administration management
Ass. Iur. Annelie Maria Lambert 3
Phone +49 531 2155-519
annelie.lambert@ist.fraunhofer.de

Business Development and Strategy
Assistant Head of Institute
Dipl.-Ing. Carola Brand 4
Phone +49 531 2155-574
carola.brand@ist.fraunhofer.de

Marketing and communications
Dr. Simone Kondruweit 5
Phone +49 531 2155-535
simone.kondruweit@ist.fraunhofer.de

IT
Andreas Schlechtweg 6
Phone +49 531 2155-633
andreas.schlechtweg@ist.fraunhofer.de

Technical services
Stephan Thiele 7
Phone +49 531 2155-440
stephan.thiele@ist.fraunhofer.de

Departmental, group and team management

Process technology and production engineering for sustainable energy storage systems
Prof. Dr.-Ing. Sabrina Zellmer 2
sabrina.zellmer@ist.fraunhofer.de | Phone +49 531 2155-528

Material and process development
Dr.-Ing. Sebastian Melzig 8
sebastian.melzig@ist.fraunhofer.de | Phone +49 531 2155-795
Product development and design / Production and conditioning of energy storage materials / Production of battery components (electrodes, separator) / Reconditioning and recycling / Material and process simulation

Sustainable process chains for battery systems
Nikolas Dilger M.Sc. 9
nikolas.dilger@ist.fraunhofer.de | Phone +49 531 2155-660
Planning, modelling, simulation of process chains and factories / Digitization of production / Sensor technology for energy storage systems / Product life-cycle analyses (technical, economical, ecological, social)

Sustainable hydrogen systems and technologies
Christoph Imdahl M.Sc. 10
christoph.imdahl@ist.fraunhofer.de | Phone +49 531 2155-669
Digital methods for energy conversion chains and sustainable factory planning / Manufacture and recycling of fuel-cell components, modules and systems / Automated assembly and testing of fuel-cell stacks

Departmental, group and team management

Sustainability management and Life Cycle Engineering

Prof. Dr. Stephan Krinke 11
stephan.krinke@ist.fraunhofer.de | Phone +49 531 2155-504

Sustainability management
Advice on corporate sustainability strategy of companies / Sustainable Development Goals (SDGs) / Materiality analysis / Resource efficiency and circular economy / Learning concepts on sustainability management and life cycle assessment

Life Cycle Engineering
Tools and methods for holistic product and process optimization / Life cycle engineering and life cycle costing / Hotspot analyses / Certified carbon and water footprint / Roadmaps for decarbonization and circular economy

Analytics and quality assurance

Dr. Kirsten Schiffmann 12
kirsten.schiffmann@ist.fraunhofer.de | Phone +49 531 2155-577
Chemical micro-range analysis / Microscopy and surface measurement / Mechanical characterization / Friction and wear measurement / Testing technology / Customer-specific testing methods / Commissioned investigations

Interfacial chemistry and adaptive adhesion

Prof. Dr. Michael Thomas 13
michael.thomas@ist.fraunhofer.de | Phone +49 531 2155-525

Atmospheric pressure plasma processes
Plasma polymerization / Process and source development for atmospheric pressure plasmas / Surface cleaning / Additive manufacturing processes / Circular economy

Electroplating and wet-chemical processes
Rowena Duckstein M. Sc. 15
rowena.duckstein@ist.fraunhofer.de | Phone +49 531 2155-619
Plastic metallization / Electrochemistry with ionic liquids / Dispersion deposition / Electroplating 4.0 / Pretreatment and recycling

Medical and pharmaceutical systems
Dr. Kristina Lachmann 14
kristina.lachmann@ist.fraunhofer.de | Phone +49 531 2155-683
Individualized pharmaceutical production and packaging technologies / Medical technology solutions (cleaning and sanitation, protective equipment, implants, disposables) / Quality assurance for manufacturing processes / Chemical functionalization and analysis

Optical systems and application

Dr. Michael Vergöhl 16
michael.vergoehl@ist.fraunhofer.de | Phone +49 531 2155-640

Precision optical coatings
Dr. Philipp Farr 17
philipp.farr@ist.fraunhofer.de | Phone +49 531 2155-645
Production technology for optical interference filters / Measurement technology for process control and quality assurance / Development and demonstration of filters in accordance with customer specifications

Optical and electrical systems
Dr.-Ing. Ralf Bandorf 18
ralf.bandorf@ist.fraunhofer.de | Phone +49 531 2155-602
Optical, electrical and magnetic functional layers / Large-area coating / Gas-flow sputtering technology / High power impulse magnetron sputtering (HIPIMS) / Sensor technology

Simulation & Digital Services
Dr. Dennis Barton 19
dennis.barton@ist.fraunhofer.de | Phone +49 531 2155-610
Kinetic and CFD simulation PIC-MC / DSMC / Cyber-physical systems / Software development / Measurement technology

Diamond-based systems and CleanTech

Dr. Volker Sittinger 20
volker.sittinger@ist.fraunhofer.de | Phone +49 531 2155-512

Atomic layer deposition
Dr.-Ing. Tobias Graumann, PMP 21
tobias.graumann@ist.fraunhofer.de | Phone +49 531 2155-780
Coating processes for medical products / Coating of 3D substrates for micro-optics and membranes / Particle coating / Catalyst deposition for energy conversion and systems

Hot-wire CVD
Dr.-Ing. Christian Stein 22
christian.stein@ist.fraunhofer.de | Phone +49 531 2155-647
Application-specific diamond coatings and processes / Solutions for diamond tools and machine elements / Development of HCVD components and production systems / Development of highly efficient solar cells

Photo- and electrochemical environmental technologies
Dipl.-Ing. (FH) Frank Neumann 23
frank.neumann@ist.fraunhofer.de | Phone +49 531 2155-658
Sustainable methods and systems for air, water and soil treatment and disinfection / Accredited testing laboratory for photocatalytic materials

Tribology and sensor technology

Dr.-Ing. Jochen Brand 24
jochen.brand@ist.fraunhofer.de | Phone +49 531 2155-600

Micro and sensor technology
Anna Schott M. Sc. 25
anna.schott@ist.fraunhofer.de | Phone +49 531 2155-674
Sensor technology for tribologically stressed systems / Force and temperature sensors / Microstructuring / Data transmission and processing / Sensors for electrical storage and converters

Tribological systems
Dr.-Ing. Martin Keunecke 26
martin.keunecke@ist.fraunhofer.de | Phone +49 531 2155-652
Resource efficient and resilient tribosystems / System analysis and evaluation / Carbon layers, hard material layers, diffusion treatments, duplex processes / Process chain including pretreatment and quality assurance

Flexible production systems
Dr.-Ing. Jochen Brand 24
jochen.brand@ist.fraunhofer.de | Phone +49 531 2155-600
Flexible production systems for surface technology / Interior for mobile applications / Reuse and recycling strategies for components

Dortmunder OberflächenCentrum DOC
Dipl.-Ing. Hanno Paschke 27
hanno.paschke@ist.fraunhofer.de | Phone +49 231 844 5453
Duplex treatments using plasma nitriding and PACVD technology / Boron-containing hard coatings / Tool coatings / Coatings for hot forming / Industrial knife coatings

Locations / Centers

Application Center

Dr.-Ing. Jochen Brand 24
jochen.brand@ist.fraunhofer.de | Phone +49 531 2155-600

Prof. Dr. Wolfgang Viöl 28
wolfgang.vioel@ist.fraunhofer.de | Phone +49 551 3705-218
Cold plasma spraying / Particle coating / Development of production-compatible plasma sources / Particle sorption and modification / Plasma characterization

Fraunhofer Center for Energy Storage and Systems ZESS

Nikolas Dilger M.Sc. 9
nikolas.dilger@ist.fraunhofer.de | Phone +49 531 2155-660

Dr.-Ing. Sebastian Melzig 8
sebastian.melzig@ist.fraunhofer.de | Phone +49 531 2155-795

Prof. Dr.-Ing. Arno Kwade 29
arno.kwade@ist.fraunhofer.de | Phone+49 531 2155-503
Development of mobile and stationary energy storage systems / Development and scaling of process technologies / Battery production / Process engineering / Design of the production system for energy storage systems / Life Cycle Management

Fraunhofer Center Circular Economy for Mobility CCEM

Prof. Dr. Michael Thomas 13
michael.thomas@ist.fraunhofer.de | Phone +49 531 2155-525
Automated cleaning and treatment processes / Functional and smart surfaces / Application of bio-based and secondary materials / Future interior concepts / Life Cycle Engineering and sustainable product design

Wasserstoff Campus Salzgitter e.V. (engl. Hydrogen Campus Salzgitter)

Christoph Imdahl M.Sc. 10
christoph.imdahl@ist.fraunhofer.de | Phone +49 531 2155-669
Hydrogen technologies / Hydrogen economy / Circular economy / Network building / Sector coupling / Sustainable factory systems / Decarbonization of industry / Continuing education

Highlights

Sustainable and decentralized: Health care in rural areas of the sub-Saharan region

The future driver and operator of the PreCare system explains the structure of the mobile care platform to the attendees.

March 06, 2023 / With the aim of being able to ensure comprehensive preclinical care in even the most remote areas of Africa, researchers from the Fraunhofer institutes for Surface Engineering and Thin Films IST and for Solar Energy Systems ISE, in collaboration with Stellenbosch University and South African Medical Research Council (SAMRC) in South Africa, have developed a mobile care platform which, on 3rd March 2023, was handed over to the NGO Rhiza Babuyile during a ceremonial event. The non-profit organization has a number of locations in South Africa and will conduct the one-year test phase of the supply unit in the Mpumalanga region.

The overall concept implemented by the Fraunhofer ISE includes further modular care elements, e. g. a water-treatment plant, a unit for the on-site production of disinfectants on demand, a refrigerator and a telecommunications unit. The required power supply is provided by photovoltaic modules and a battery, as the self-sufficient flexible use of all the components is an essential prerequisite for the successful application in the target region.

Under the motto "Made in Africa for Africa", our long-term goal is to establish series production locally, not only in order to improve local healthcare and provision, but also to create jobs while simultaneously enabling local value creation.

During the trial period, medical professionals will conduct decentralized examinations of sick people and various groups of the population, e. g. pregnant women, and provide them with information regarding, for example, further treatment options and preventive examinations. Furthermore, the medicines, vaccines and examination equipment such as blood-pressure gauges or ECGs that are on board enable rapid primary care to be provided on site.

The first prototype of the care unit mounted on a Volkswagen Amarok.

The Fraunhofer Future Foundation is enabling the development of the mobile PreCare platform through the provision of funding amounting to around 0.6 million euros. With its funding program, the Foundation supports research projects that focus on the needs of civil society. In the selection of these projects, it is guided by the United Nations' Sustainable Development Goals (SDGs), such as enabling access to basic healthcare for as many people as possible worldwide.

Future Day at the Fraunhofer IST

"We coat glass"

April 28, 2023 / It has now become a tradition at the Fraunhofer IST: The institute provided 24 children with an insight into the work of a research institute.

Within the framework of Future Day and according to the motto "We coat glass", 16 girls and 8 boys were able to experience at first hand the individual stations of the process chain at the Fraunhofer IST. The activities began with a tour of the modular cleaning system. The pupils, aged between 11 and 16, were then allowed to design their own glass and prepare it for coating. By loading the magnetron sputtering system and pressing the start button, they commenced the next phase of the process – the actual coating. The thin layer was thereby deposited on the painted and unpainted areas of the glass. Through subsequent wiping of the painted areas, high-contrast images became visible. Finally, the quality control was, of course, absolutely essential: By looking through a microscope, the pupils were able to analyze "their" coatings, amongst other items.

The glasses were painted and inscribed by the pupils according to their own wishes.

Groundbreaking ceremony for the new institute building of the Fraunhofer ZESS: Dr.-Ing. Julian Schwenzel, Director of the Fraunhofer ZESS, Prof. Dr.-Ing. Sabrina Zellmer, Head of Department at the Fraunhofer IST, Dr.-Ing. Christian Wunderlich, Deputy Director of the Fraunhofer IKTS, Prof. Dr.- Ing. Matthias Busse, Institute Director of Fraunhofer IFAM, Dr. Thorsten Kornblum, Lord Mayor of the City of Braunschweig, Falko Mohrs, Minister for Science and Culture of the State of Lower Saxony, Prof. Dr.-Ing. Christoph Herrmann, Institute Director of Fraunhofer IST, Prof. Dr.-Ing. Arno Kwade, Vice President of TU Braunschweig, Dr. Patrick Hoyer, Central Research Coordinator of the Fraunhofer-Gesellschaft (l.t.r.).

Fraunhofer Center for Energy Storage and Systems ZESS

Groundbreaking ceremony for Fraunhofer ZESS institute building in Braunschweig

June 07, 2023 / The Fraunhofer Center for Energy Storage and Management Systems ZESS is centered around the development of system solutions for energy storage and hydrogen technologies. To achieve this, the three research partners – the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM, the Fraunhofer Institute for Surface Engineering and Thin Films IST and the Fraunhofer Institute for Ceramic Technologies and Systems IKTS – are being provided with a new institute building at the Braunschweig Research Airport. The groundbreaking ceremony on June 7, 2023 marked the start of construction on a research building comprising over 3,400 square meters of floor space.

Fraunhofer ZESS represents the value chain for mobile and stationary storage technologies – its research focuses on lithium solid-state batteries, sodium nickel chloride batteries and hydrogen technologies.

February 7, 2019 saw the launch of Fraunhofer ZESS. Since then, scientists from the three Fraunhofer institutes have been conducting research and making developments on a transitional basis in close collaboration with the Technical University of Braunschweig at the premises of the Automotive Research Centre Niedersachsen (NFF) and at the neighboring Lilienthalhaus at the Forschungsflughafen. The German state of Lower Saxony and the Fraunhofer-Gesellschaft have provided 20 million euros in start-up funding.

The new building will help to establish a unique infrastructure and research platform that are vital for developing and implementing future energy storage systems from the prototype stage right through to industrialization – as well as providing space for over 100 employees. Fraunhofer ZESS currently has 75 employees, over 50 of whom are already located at the Braunschweig office. The costs for constructing and equipping the new building amount to approximately 46 million euros, which was provided by the German federal government and the German state of Lower Saxony. The researchers will be able to use the new technical equipment and laboratories from 2025.

Numerous sectors of industry and technologies depend directly or indirectly on new energy storage systems being developed: Electric cars require efficient batteries, and stationary electricity storage systems can stabilize electricity networks that are supplied by renewable energy sources which fluctuate over time, such as photovoltaic systems or wind turbines. Germany is very well placed internationally in terms of materials research and process development for energy storage systems. As such, Fraunhofer ZESS is in the position to develop innovative contributions and deliver efficient, climate-friendly responses to societal and environmental challenges.

Perspective forecourt "Fraunhofer Center for Energy Storage and Systems ZESS".

Interior view "Fraunhofer Center for Energy Storage and Systems ZESS".

New professorship links Fraunhofer IST and TU Braunschweig

July 10, 2023 / Prof. Dr.-Ing. Sabrina Zellmer, Head of Department at the Fraunhofer Institute for Surface Engineering and Thin Films IST in Braunschweig, has taken on not one but two new functions simultaneously. In April, Prof. Zellmer was appointed Professor for Battery and Fuel-Cell Process Technology at the Technische Universität Braunschweig. Located at the Institute for Particle Technology (iPAT), the professorship further strengthens the close alliance between the TU Braunschweig and the Fraunhofer IST. In addition, Prof. Sabrina Zellmer has held the position of Deputy Director of the Fraunhofer IST since 1st July 2023.

For the past four years, Sabrina Zellmer has been Head of Department, Process Technology and Production Engineering for Sustainable Energy Storage Systems at the Fraunhofer IST. On the 15th of April, she was appointed professor at the TU Braunschweig. The tenure-track professorship is part of the federal- and state-government program for the promotion of young scientists. The professorship enhances the link between the university and the Fraunhofer IST, and will strengthen the joint profile in research and teaching related to batteries and fuel cells.

In the future, Sabrina Zellmer will also be active as the new Deputy Director of the Fraunhofer IST. The previous Deputy Director of the Institute, Dr. Lothar Schäfer, went into retirement at the end of June.

Dr. Sabrina Zellmer (centre) was appointed Professor of Battery and Fuel-Cell Process Technology at TU Braunschweig. Presentation of the certificate with President Professor Angela Ittel (left) and Professor Markus Böl, Dean of the Faculty of Mechanical Engineering.

The floating knowledge platform "Oker Space".

Floating knowledge platform "Oker Space"

August 22,2023 / This summer, the knowledge platform floating on the Oker river in Braunschweig provided visitors with information in the form of posters that focused on the areas of education, water-treatment technologies and ecological sustainability.

"Clean water through diamond" is the topic introduced by the Fraunhofer IST on the raft, thereby providing an overview of its expertise in the field of water treatment by means of diamond technology.

Structural change powered by Fraunhofer IST

3.1 million euros for structural change in the Wilhelmshaven region

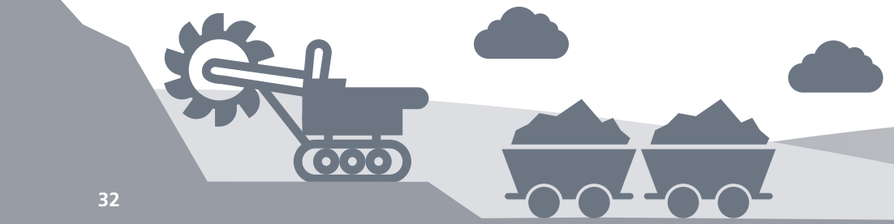
November 02, 2023 / The Wilhelmshaven region will receive 3.1 million euros for the further implementation of structural change. The money will flow into the "Transformation Wilhelmshaven" project which is being conducted by the Fraunhofer Institute for Surface Engineering and Thin Films IST and the Jade University of Applied Sciences. "Transformation Wilhelmshaven" is intended to help strengthen local transition in the industrial structure and the energy industry in order to increase value creation in the region, thereby sustainably improving the quality of life.

> **"Wilhelmshaven is already a key player in the energy transition today and will provide a significant contribution towards accelerating this development in the future by supplying Germany's industry with climate-friendly hydrogen and establishing itself as a leading location for sustainable production and value creation."**
>
> **Prof. Dr.-Ing. Sabrina Zellmer, Deputy Director**

The funding stems from the so-called "Kohlemittel" (coal funds), which are provided by the federal government for the management of structural change in the former coal-mining areas and which are administered by the Niedersächsisches Ministerium für Bundes- und Europaangelegenheiten und Regionale Entwicklung (Lower Saxony ministry for federal and European affairs and regional development). The Federal Office of Economic Affairs and Export Control (BAFA) has now approved the funding. It will run for three years.

The "Transformation Wilhelmshaven" project aims to identify future prospects beyond the coal industry. Research is also thereby being conducted into new potential outside of the energy industry and the energy system transformation. In collaboration with local companies, fields of action will be identified based on the strengths and weaknesses of the region. Within these, project alliances can be created in the form of research, transfer and innovation alliances. Potential branches of industry in the field of energy transition can be found, in particular, in the hydrogen and recycling sectors. Furthermore, medium-sized companies from the region can receive advice on structural change. One focus is on further training programs in the field of the hydrogen economy.

For additional information on this project, please refer to our profile on page 52 and 53.



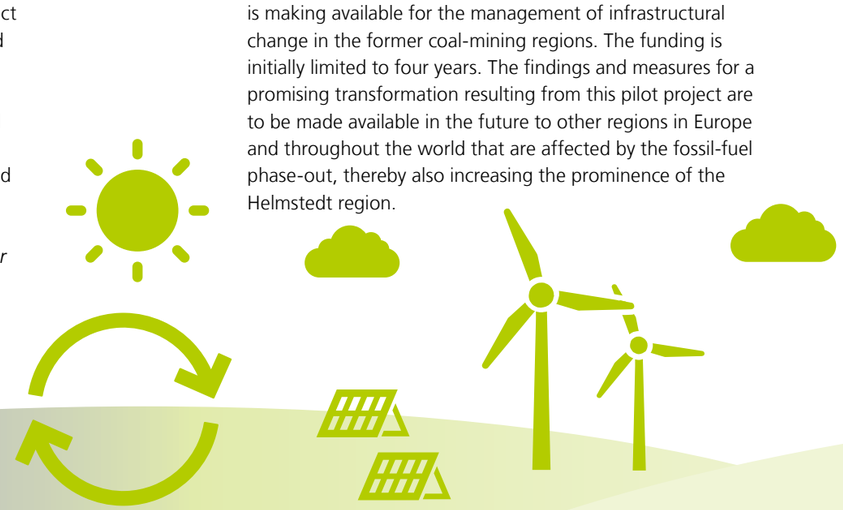
Fraunhofer IST founds innovation center in Helmstedt

November 21, 2023 / The funding sum of more than one million euros from structural-reinforcement funds will be utilized for the project carried out by the Fraunhofer institutes IST and IKTS: "Development and establishment of an innovation center by the Fraunhofer IST as a driving force behind transfer measures for knowledge and technology".

Thomas Klein, Managing Director of Wirtschaftsregion Helmstedt GmbH (left) and Dr. Guido Hora from the Fraunhofer IST (right).

In close cooperation with Wirtschaftsregion Helmstedt GmbH and in collaboration with regional partners from business, science and politics, the project aims to help strengthen the local transformation in the areas of technology and services for the energy transition, resource efficiency through the circular economy and sustainable digital agriculture in order to increase value creation in the region. For this purpose, the Fraunhofer-Gesellschaft will establish an office in the Haus der Wirtschaft, the home of Wirtschaftsregion Helmstedt GmbH, from 2024 and the flag of science will then fly prominently in the district town.

In collaboration with regional companies, fields of action in the energy, circular-economy and agriculture sectors are to be identified and, with the support of the Technische Universität Braunschweig and Ostfalia University of Applied Sciences, new companies are to become established and project alliances formed. The funding stems from the so-called "Kohlemittel" (coal funds), which the federal government is making available for the management of infrastructural change in the former coal-mining regions. The funding is initially limited to four years. The findings and measures for a promising transformation resulting from this pilot project are to be made available in the future to other regions in Europe and throughout the world that are affected by the fossil-fuel phase-out, thereby also increasing the prominence of the Helmstedt region.



Participation in trade fairs and exhibitions

In the reporting year 2023, the Fraunhofer IST once again participated in a number of trade fairs and exhibitions in order to present the institute's latest research results to a specialist audience. Furthermore, one focus this year was on presenting the Fraunhofer IST's attractiveness as an employer at job and career fairs.

At this year's HANNOVER MESSE from the 17th to the 21st of April 2023, the Fraunhofer IST participated in the joint stand of the Fraunhofer-Gesellschaft with the topics "Sustainable process chains for materials processing" within the framework of the Group for Production, and "Thin-film sensor technology for future monitoring" within the framework of the Adaptronics division. Furthermore, the institute was represented as a partner of the Wasserstoff Campus Salzgitter on the joint stand Lower Saxony "Energy | Industrial Supply". During the visit of Lower Saxony's Minister of Economic Affairs, Olaf Lies, follow-up projects were presented which address factory transformation in order to decarbonize the value chain; the stacking plant for fuel-cell stacks, currently under construction; and the planned recycling line.

Personal exchange of information with the public in the Braunschweig region

How can surface technology and digitalization contribute towards preventing infection and protecting patients? What contributions does digitalized research provide with regard to environmental protection? These questions were answered by employees of the Fraunhofer IST at the "Salon der Wissenschaft" (Science Salon) on 10th May 2023. The format is organized by ForschungRegion Brauschweig e.V. and the City of Braunschweig in order to bring science to life for the public and to promote the exchange of information between science and society. The focus of the event is thereby formed not by traditional lectures, but instead by interpersonal dialog. In a number of parallel rounds, participants were able to exchange ideas in person with scientists from the Braunschweig region on topics such as sustainability, climate protection, digitalization, healthcare, mobility and education.

At the HANNOVER MESSE, on the Fraunhofer joint stand in the Production section, the Fraunhofer IST trade-fair team demonstrated the potential of coating and surface technology for the manufacture of sustainable tools.

The team from the Wasserstoff Campus Salzgitter took advantage of the visit of Lower Saxony's Minister of Economic Affairs, Olaf Lies, to the HANNOVER MESSE to discuss topics relating to the development of Salzgitter as a model region for hydrogen (from left to right: Prof. Sabrina Zellmer, Dr. Christine Blume, Prof. Christoph Herrmann, Michael Gensicke, Olaf Lies, Kolja Backsmann).

Using the MOCCA+® software as an example, a system for improved process control and for the automated process management of coating processes was demonstrated live at this year's LASER.

This year, the Fraunhofer IST team attended diverse career-orientation fairs in the region in search of trainees and students.

Find and be found...

The Fraunhofer IST took part in no fewer than five trade fairs and events this year in order to counteract the shortage of skilled workers. At the bonding company contact fair, two TU Braunschweig bachelor info evenings, the "Markt der Möglichkeiten" (Market of Opportunities) and the parentum job and career fair, the institute presented itself in order to get to know pupils and students who are interested in working at the Fraunhofer IST on sustainable solutions for surfaces as well as coatings for future-oriented products and production systems.

Fully automated monitoring and control of the production of optical coatings

From the 27th to the 30th of June 2023, the Fraunhofer IST presented its in-house-developed MOCCA+® software at the LASER World of PHOTONICS, the world's leading trade fair for photonics components, systems and applications. This software can be used both for optical broadband monitoring of the individual layers of a filter and for controlling the EOSS® system (Enhanced Optical Sputtering System). The functions of the software include process and production planning, substrate handling, and routines for automatic shutdown and restart in the event of power failures. In addition, the software learns continuously from the processes being performed. The user of the system does not have to intervene between individual coating applications.

Online format "TransferTalk" from the Fraunhofer IST

On the 20th of June 2023, the new free online event format "TransferTalk – Industry meets Science" celebrated its premiere with three to-the-point presentations followed by a discussion on the topic of "Hydrogen technologies along the value chain". In addition to finding out how hydrogen can be produced from biogenic residues, around 50 participants also learned about the latest developments in materials and measurement methods for the hydrogen economy and how they can digitally support the transformation of a company in such a way that it is also economically viable. On 17th October 2023, the TransferTalk entered its second round with the topic "Surface analytics in quality assurance".

To be continued…

Continuing education

In the reporting year 2023, we conducted five courses with 31 participants in collaboration with the Fraunhofer Academy. The response was thoroughly positive. Further courses are planned for 2024, and a new continuing-education program on the topic of sustainability "think GREEN, act SMART – Introduction to sustainability for companies" is being launched. Our programs at a glance:

"Net Zero Scenario – how to achieve it with hydrogen"

Since 2022, the Fraunhofer IST, in collaboration with the Fraunhofer Academy, has been offering training programs for qualification in the hydrogen economy. In the training program "Practical energy transition – Expertise for your changeover to hydrogen", participants can learn, amongst other things, how to produce, transport and utilize green hydrogen.

Basic module

The basic module is targeted at people who want to acquire a solid basic knowledge of the topic of hydrogen and who enjoy self-determined learning. Participants learn about the entire value chain of the hydrogen economy and discover why hydrogen is a key element for a climate-neutral economy and which factors are important for their companies when changing over to hydrogen.

Certification course

Within the framework of the "Net Zero Scenario – how to achieve it with hydrogen" training program, a certificate course was offered for planners, management representatives, engineers, employees of municipal utility companies, master craftsmen and experts who want to proactively understand the opportunities of utilizing hydrogen. The course offers the possibility of obtaining the TÜV personal certificate and, following successful completion of the examination, the title "Hydrogen expert with TÜV Rheinland-certified qualification".

In the reporting year, five participants completed the basic course in German. The certificate course in German ran three times with a total of 21 participants, and the course in English took place once with five participants.

Furthermore, the Fraunhofer IST offered a one-day seminar "Hydrogen - Perspectives for industry and commerce" on 9th May 2023 in cooperation with AGIMUS GmbH.

In the year under review, the "Net Zero Scenario – how to achieve it with hydrogen" training course was held as a basic module and as a face-to-face and online certificate course in both German and English.

Following the sustainability training, participants are able, amongst other things, to recognize the relevance of sustainability and Life Cycle Assessments (LCA) within their own company along the path towards climate neutrality.

think GREEN act SMART: Introduction to sustainability for companies

In April 2024, a new training program will be launched. "think GREEN act SMART: Introduction to sustainability for companies" is targeted at (prospective) sustainability officers and managers as well as employees from purchasing and sales who want to address the topic of sustainability or understand supply chain requirements. This training course will also offer the possibility of obtaining a personal certification from the Fraunhofer Personnel Certification Authority. The Fraunhofer IST is hoping for keen interest and active participation.

Information on the current range of continuing-education programs can be found on our website:

In focus

Into the future with sustainable energy

The success of a company is massively influenced by its sustainability performance.”

Prof. Dr.-Ing. Christoph Herrmann, Director of the Fraunhofer IST

For years, energy prices have been rising – an effect that has been exacerbated by the war of aggression in Ukraine. While energy demand and prices are increasing, fossil resources are dwindling and climate-related disasters are becoming part of our lives.

Reports of forest fires, floods and heatwaves are a constant reminder: Climate protection concerns us all. In order to protect the global climate, the EU has committed itself to limiting emissions and, consequently, to converting to green energy sources. In this time of multifactorial crises, it is important for the Fraunhofer IST to develop robust and sustainable solutions.

In order to achieve the goals of the Paris Climate Agreement and climate neutrality by 2050, the European Climate Law obliges EU member states to significantly reduce greenhouse gas emissions. In 2019, the industrial sector was responsible for 24 % of greenhouse gas emissions worldwide, whilst the transport sector was responsible for 15 %[1]. The automotive sector is one of Germany’s most important industries and a pioneer for sustainable development. The OEM’s decarbonization targets thereby encompass the entire life cycle – “from the cradle to the grave”. To achieve these goals, the product portfolio is being electrified and the supply chain decarbonized.

The Fraunhofer IST develops customized tools that make CO_2 measurable along the entire value chain and identify the technologies with the most favorable CO_2-reduction costs. Our work focuses on methods for measuring sustainability in the life cycle as well as on batteries, hydrogen, photovoltaics and technologies for the achievement of a circular economy.

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[1]Lee, H., Romero, J., (2023): Climate Change 2023: Synthesis Report. Intergovernmental Panel on Climate Change (IPCC), Geneva, Switzerland.

Sustainability

Sustainability is a tough competitive factor in industry, as sustainability rankings influence the share price and market capitalization of companies. Legal requirements such as the EU's Corporate Sustainability Reporting Directive (CSRD) demand a science-based derivation of sustainability targets. The Sustainability Management department at the Fraunhofer IST provides companies with advice and support in strategy development, target derivation and the development of measures.

What can be measured can also be managed: Tools for the quantification of sustainability

Based on the requirements of customers, competition, legislation, the financial market and technological trends, we identify the relevant target areas. The focus is formed by decarbonization, water efficiency and the circular economy.

We provide our customers with materiality analyses, tools for measuring the sustainability performance throughout the life cycle, certified carbon footprints and decarbonization roadmaps. In the area of further training, we offer courses on sustainability and Life Cycle Assessments in order to anchor sustainability within the workforce.

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> "CO_2 is the currency of the future."
>
> **Prof. Dr. Stephan Krinke,**
> **Head of Department at Fraunhofer IST**

SUSTAINABLE DEVELOPMENT GOALS

Silicon layers produced by hot wire CVD for a heterostructure solar cell.

Our sun provides more energy than mankind can ever use for its own supply. The development and provision of technologies for utilizing this free energy source is crucial for our future.”

Dr. Volker Sittinger, Head of Department at Fraunhofer IST

Photovoltaics

The future energy supply for the world will be based on photovoltaics and wind energy. Thanks to silicon-based solar cells, photovoltaics is now one of the most economical sources of electricity worldwide, depending on location.

According to the World Energy Outlook 2020 published by the International Energy Agency IEA, the cost of generating electricity from photovoltaics in Europe lies between 2.7 and 5.4 €ct/kWh for large-scale greenfield installations[2]. Highly efficient solar cells are therefore strategically one of the most important optoelectronic components of the future.

The latest generations are based on the application of vacuum technology for the creation of virtually defect-free interfaces with optimized optoelectronic adaptation to the photovoltaic absorber.

The further development of cell technology towards higher efficiencies is necessary in order to facilitate a reduction in the electricity generation costs, material costs and, as a result, area-related scaling effects. Promising new cell technologies are presented by tandem solar cells based on established silicon and CIGS technologies in combination with perovskite as an additional absorber material. Tandem solar cells have a very complex structure.

They are comprised of a large number of wafer-thin contact layers that are deposited under, between and on the two absorbers. At the Fraunhofer IST, we have acquired extensive expertise in the field of vacuum technologies, which we apply here in order to realize highly efficient processes and, at the same time, excellent layer properties for e.g. transparent conductive layers, tunnel and front contacts or hole and electron contact layers.

The scaling-up of the technologies forms a further focus of our work. Our customers and partners benefit not only from our expertise in the development of layers for photovoltaics or in simulation for process optimization, but also from our measurement technology for quality assurance and control. Furthermore, we carry out Life Cycle Assessments and design the entire product life cycle with regard to sustainability within the scope of our Life Cycle Engineering.

[2]IEA World Energy Outlook 2020, p. 238, https://www.iea.org).

The energy transition is crucial for a secure, environmentally friendly and economically successful future. It can, however, only succeed if energy generation, conversion and storage technologies are made even more efficient, cost-effective and environmentally friendly. Essential for this is the holistic and sustainable design of the production systems and life cycles of current and future energy storage systems.

Batteries

For the achievement of these overarching goals, aspects such as the establishment of European gigafactories for the production of battery cells, the energy-efficient operation of these factories, the provision and extraction of raw materials under ecological, economic and social aspects, compliance with the European Battery Directive and the transfer of production concepts to future battery chemistries, etc. are of crucial importance.

Would you like to expand your knowledge in the field of battery research, or do you perhaps have a specific inquiry?

In our further-training program “EPR for Batteries” (Extended Producer Responsibility), you will acquire basic theoretical knowledge regarding the entire life cycle of a battery, including the legal framework conditions. Furthermore, the further-training program was developed in cooperation with the Stiftung GRS Batterien und GRS Service GmbH and therefore also includes topics such as the collection and safe storage of used batteries. In a concluding face-to-face workshop, the requirements and responsibilities of individual decision-makers are discussed in order to successfully transfer the acquired knowledge into practice.

Electrodes for the production of battery cells.

“High-performance, sustainably produced battery storage systems are key technologies for a low-carbon energy infrastructure and a clean future.”

Dr.-Ing. Jutta Janßen, Head of Education Management for Circular Production at Fraunhofer IST

Hydrogen

You too can become a hydrogen expert by taking part in our training program."

Prof. Dr.-Ing. Sabrina Zellmer, Head of Department and Deputy Director of the Fraunhofer IST

The hydrogen economy is a key element in the defossilization of the global energy system and promotes the achievement of the UN's Sustainable Development Goals.

In the future, hydrogen will be used in the industrial, energy and transportation sectors in applications in which direct electrification is not feasible, e.g. as a reducing agent in the steel industry or for the production of methanol and ammonia. Less than 1 percent of today's hydrogen demand of 95 million metric tonnes is based on climate-friendly production routes. The International Renewable Energy Agency IRENA predicts an increase in future demand to around 614 million tonnes by 2050[3]. The focus lies on electrolyzers in order to produce green hydrogen using electricity from renewable energies. In addition, a global market for hydrogen and its downstream products is being based on the differing generation potentials from renewable energies.

The Fraunhofer IST offers solutions for a sustainable hydrogen economy. These include processes for the production and recycling of electrolyzers and fuel cells.

In addition, the institute offers digital planning tools and evaluation models for the economic application of hydrogen technologies in factory systems and for the supply of hydrogen via regional and intercontinental supply chains.

Participation in our further-training program will equip you with comprehensive expertise and the skills needed to support the transition from fossil fuels to climate-neutral alternatives. Following completion of the further-training program, you will be able to apply the technical and regulatory expertise regarding the creation of green hydrogen. You will be in a position to identify the requirements and challenges arising through the transition to green hydrogen and to transfer these to a range of applications. You will also be able to outline a hydrogen production system and to describe the fundamental challenges of planning and technical operation. This qualification will enable you, as a pioneer of decarbonization, to actively contribute towards the transformation of the coal regions in Central Germany.

[3]IRENA (International Renewable Energy Agency)

Contact

Photovoltaics
Dr. Volker Sittinger
Phone +49 531 2155-512
volker.sittinger@ist.fraunhofer.de

Sustainabiliy management
Prof. Dr. Stephan Krinke
Phone +49 531 2155-504
stephan.krinke@ist.fraunhofer.de

Sustainable energy storage
Prof. Dr.-Ing. Sabrina Zellmer
Phone +49 531 2155-528
sabrina.zellmer@ist.fraunhofer.de

Continuing education
Dr.-Ing. Jutta Janßen
Phone +49 531 2155-613
jutta.janssen@ist.fraunhofer.de

Our expertise

along the entire process chain

Optics

Digital economy

Space travel

Diamond-based systems and CleanTech

Vehicle construction

Environmental technology

Sustainability management and Life Cycle Engineering

Energy

Process and production engineering for sustainable energy storage

Agricultural and food industry

Tools

Plant and mechanical engineering

Medical and pharmaceutical process engineering

Sensor technology

Analytics, quality assurance testing technology

Aviation

Interfacial chemistry and adaptive adhesion

Chemical industry

Tribology

Process and production engineering for sustainable energy storage

Sustainable energy storage for a successful transformation

What are the focal points of the department?

The main focus areas of the "Process and production engineering for sustainable energy storage" department are material and process development for recyclable energy storage systems as well as the design of factory systems for the production of energy storage systems, including hydrogen technologies. Our core competencies here lie in the area of economic and ecological evaluation for production systems as well as process optimization through multi-scale simulation and process monitoring for energy storage technologies. Furthermore, we aim to achieve a holistic and sustainable design for the entire life cycle of energy storage systems in terms of Life Cycle Management – from material production, through the various production stages and utilization, and on to recycling."

What were the highlights in the reporting year?

This year once again featured a number of highlights in our three departments, driven in particular by our excellent team of scientific and technical staff. In the field of hydrogen technologies, these included the founding of the Wasserstoff Campus Salzgitter e. V., and the ScaleH2 project in collaboration with Australian partners which is aimed at developing solutions to the question of "How can green hydrogen be cost-effectively transported from Australia to Germany?". In the area of battery cell production and Life Cycle Management, our new training course "think GREEN, act SMART – Introduction to sustainability for companies" as well as projects in the field of battery modeling, such as NaNiBatt or HELENA, should be mentioned."

What are the plans for the future?

In the area of battery and hydrogen technologies, we want to further expand our infrastructures, amongst other things. This includes the Fraunhofer Center for Energy Storage and Systems ZESS – which is currently under construction at Braunschweig Research Airport – where we want to continue to drive forward the further development of solid-state batteries and stationary systems in collaboration with our colleagues from the Fraunhofer institutes IFAM and IKTS. Furthermore, a milestone for 2024 is the further elaboration of the dismantling and recycling of fuel-cell systems as well as the continued elaboration of the Wasserstoff Campus Salzgitter."

Electrodes for the production of battery cells.

#WeKnowSolutions

- Customized and practical further training and consulting
- Studies and concepts for sustainable energy systems in industrial clusters, factories and districts
- Development of energy system simulations
- Holistic, sustainable consideration and development of battery and hydrogen technologies
- Unique and interdisciplinary research infrastructures with partners from research and industry throughout the region
- Production and analysis of materials, components and cells or stacks for batteries and fuel cells

Contact

Prof. Dr.-Ing. Sabrina Zellmer
Phone +49 531 2155-528
sabrina.zellmer@ist.fraunhofer.de

From research

Energy hub – Transformation of the Wilhelmshaven region

Transformation WHV

Energy imports into Germany covered around 74 percent of the country's primary energy consumption in 2019 and are dominated by fossil fuels such as hard coal. As a result of the energy transition, the seaport location of Wilhelmshaven will have to undergo a transformation process in record time, thereby developing into a hub for low-carbon and renewable energy sources such as hydrogen (energy hub).

The Fraunhofer IST is supporting this process as a scientific partner through its expertise in the field of energy storage and systems.

Along the value chain, fields of action in the energy industry and energy system transformation as well as related fields of technology are identified, analyzed and incorporated into the transformation process.

The transfer of innovative, climate-friendly technologies is crucial for a sustainable industrial society. Through the promotion and strengthening of the regional energy sector, the industry is provided with support and the quality of life – both within and beyond the region – is sustainably improved.

The project

Transformation Wilhelmshaven – Technologische und strategische Handlungsfelder für die Region Wilhelmshaven (Technological and strategic fields of action for the Wilhelmshaven region)

Duration

2023 to 2026

Project partner

- Jade University of Applied Sciences

Funding body

German Federal Office for Economic Affairs and Export Control (BAFA)

First oil and coal, and soon hydrogen: Wilhelmshaven – the only deep-sea port in Germany – will undergo a transformation process in order to enable the import of climate-friendly energy sources.

Contact

Prof. Dr.-Ing. Sabrina Zellmer
Phone +49 531 2155-528
sabrina.zellmer@ist.fraunhofer.de

Tribology and sensor technology

Resilient and intelligent tribo systems

What are the focal points of the department?

Friction, wear and corrosion cause damage running into billions of euros every year, thereby harming the environment and even endangering human lives. We develop high-performance surfaces for resilient tribological systems and adapt them precisely to customer-specific requirements. As a result, the systems consume less energy and are more durable. Furthermore, additional functions can be realized. We thereby always consider each and every process step necessary for cost-effective production, and develop individual, highly resilient sensors for the continuous monitoring of such tribological systems, with which incipient damage can be detected promptly."

What were the highlights in the reporting year?

In the context of the digitalization of production processes or products, the acquisition of data via high-performance sensors is becoming increasingly important. We develop widely differing sensor types for use in highly stressed tribological systems, e. g. on forming and prototype tools, but also on any type of machine element. The sensor technology enables real-time monitoring of the tool load and, consequently, individual adaptation of the production processes. Furthermore, tools can be replaced in good time before a final failure occurs."

What are the plans for the future?

Further developments in materials technology, production technology and digitalization as well as increasing ecological requirements, such as the renunciation of fluorinated hydrocarbons, are constantly presenting us with new challenges. The requirement profiles for surfaces are constantly increasing and new functionalities have to be implemented. At the same time, however, cost pressure is also growing. In order to meet these requirements, we will have to combine different surface technologies more and more frequently in the future and, at the same time, reduce the costs of the necessary processes."

Mold core with temperature sensor for aluminum die casting.

#WeKnowSolutions

- Analysis and design of tribological systems
- Development and adaptation of surfaces to customer-specific requirements
- Performance of tribological tests and characterization of surfaces
- Development of application-specific thin-film sensors
- Bio-inspired surfaces and bio-based processes for surface design
- Digitalization of surface-technology processes

Contact

Dr.-Ing. Jochen Brand
Phone +49 531 2155-600
jochen.brand@ist.fraunhofer.de

From research

Economical production of metallic bipolar plates

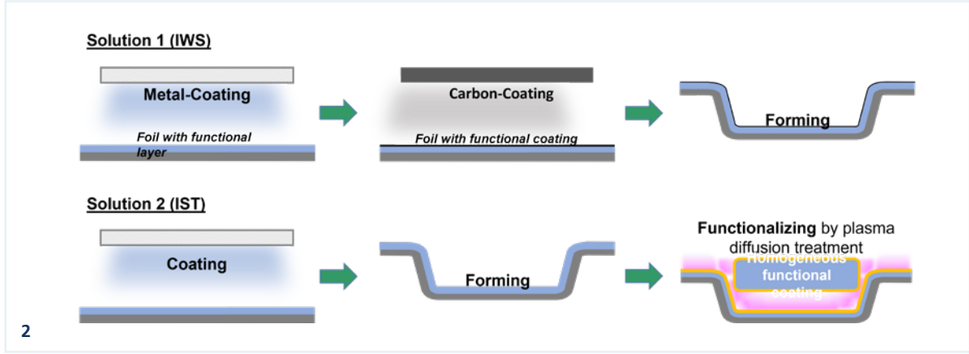
BPP coating

The application of PEM fuel cells (polymer electrolyte membrane fuel cells) offers promising prospects for stationary energy generation, electromobility and the reduction in dependence on fossil fuels; it is, however, currently limited by cost-intensive large-scale production.

The bipolar plate (BPP) is one of the most cost-intensive components in the PEM fuel cell. As a result of its operating conditions, it is subject to high demands in terms of electrical conductivity and corrosion resistance. The “BPP coating” project is focused on improving these properties, increasing the service life, and enabling economical production through the development and testing of new production methods for metallic BPPs. Within the framework of the project, two different solution approaches are being pursued, each of which combines different coating and shaping processes such as embossing or hydroforming (see Figure 2).

The Fraunhofer IST solution approach is based on metallic foils coated with titanium, which are functionalized through plasma diffusion treatment following forming (see Figure 1). As a result, the defects caused by forming should be minimized and, at the same time, corrosion resistance should be improved.

The performance capability of the differing approaches is being investigated in various forming processes. The aim is the development of a cost-effective, efficient and scalable production process for BPPs. In this way, the production of key components for the utilization of green hydrogen is to be developed, thereby providing a contribution towards the energy transition in Germany and Europe.



Schematic representation of the solution approaches pursued in the project.

The project

Development of production-process sequences for coated metallic bipolar plates for fuel cells of the highest quality and energy efficiency

Duration

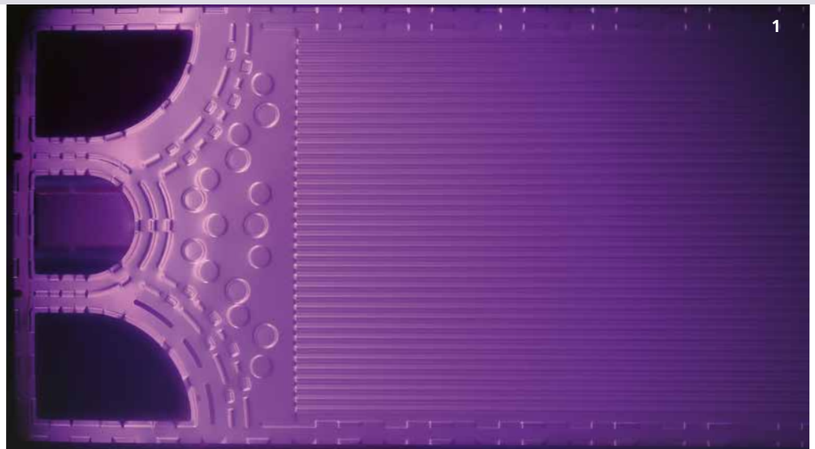
07/01/2023 - 06/30/2025

Project partners

- Fraunhofer Institute for Machine Tools and Forming Technology IWU
- Fraunhofer Institute for Material and Beam Technology IWS

Funding bodies

- Industrial Collective Research IGF
- European Society of Thin Films (EFDS)



Functionalization of a metallic bipolar plate by means of plasma nitriding.

Contact

Phillip Marvin Reinders M.Sc.
Phone +49 531 2155-835
phillip.reinders@ist.fraunhofer.de

From research

Sensor technology for AI-supported quality monitoring in production technology

AI-NET-ANIARA

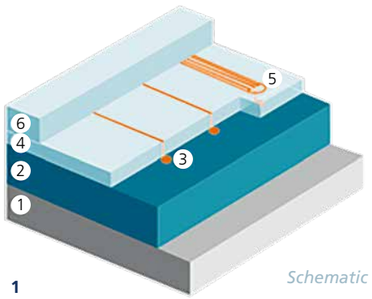
In order to be able to monitor production processes automatically with the aid of AI, innovative sensor systems are required that provide, with the highest possible data quality, real-time information regarding the status of the product and process. In the "AI-NET-ANIARA" project, the Fraunhofer IST therefore conducted work on the development of innovative thin-film sensors for automated production processes using the example of plastic injection molding.

The potential of thin-film sensor technology

The application of the thin-film sensors developed at the Fraunhofer IST (see Figure 1) in combination with AI opens up the technological prerequisites for the implementation of autonomously controlled systems. Human operators thereby receive support in recognizing the product status within the production process and in initiating the available options for optimization and control measures as required.

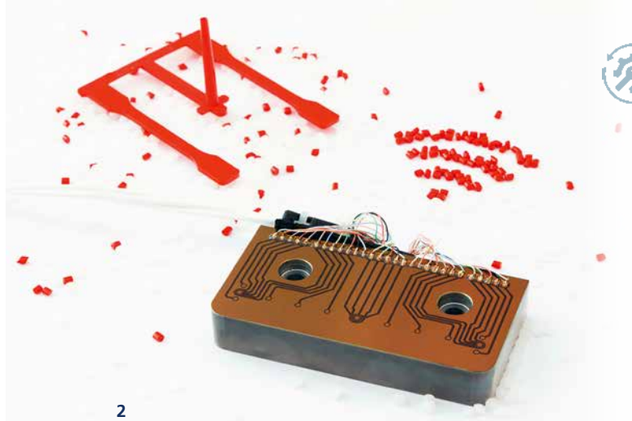
Structure of the thin-film sensor

At the Fraunhofer IST, a multifunctional thin-film sensor system (see Figure 2) was deposited on steel inserts by means of physical and chemical vacuum deposition (PECVD), which can be easily integrated into the tool. The base layer consists of a thermoresistive and wear-resistant diamond-like carbon (DLC) layer. An array of 13 electrode structures made of chromium was structured on top, mapping the flow front along the component geometry. This is followed by two electrical insulation layers made of SICON®, between which the chromium-based conductor tracks were produced using photolithographic processes.



1. Tool insert (1.3505)
2. Sensory layer (DLC / 6 µm)
3. Elektrode structures (Cr / 0.2 µm)
4. Insulating layer (SICON® / 1 µm)
5. Meander structure (Cr / 0.2 µm)
6. Insulating and wear-protection layer (SICON® / 3 µm)

1 *Schematic representation of the multifunctional layer system.*

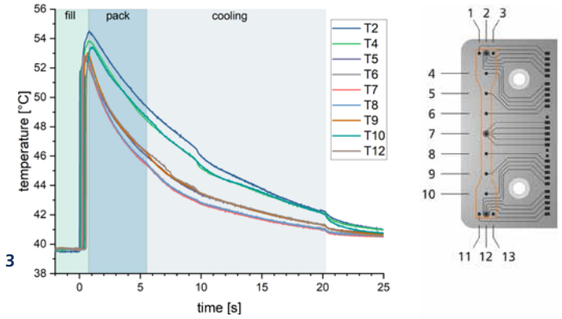


2 *Sensory tool inserts with 13 measuring points, injection molding sample and plastic granulate.*

The entire layer system has a thickness of around 10 µm. A measuring system adapted to the thin-film sensors was developed for data acquisition. For data evaluation and analysis of the product condition, the measurement data is sent to an edge device, which analyses the measurement data using an AI algorithm and displays the quality of the injection-molded component via a color signal directly on the machine even before the tool is opened.

Outlook: Application of the sensor system in incremental manufacturing

The developed sensor system was tested on the injection-molding machine at the Institute of Machine Tools and Production Technology (IWF) at the TU Braunschweig. A temperature profile is shown exemplarily in Figure 3. As a sub-process of incremental manufacturing, digitalized and intelligent manufacturing strategies for the efficient manufacture of functionalized products in differing quantities were investigated with the aid of sensor technology. It was found that as a result of the increased data availability in combination with the application of machine learning processes, individualized (intermediate) product states can be predicted and suitable optimization strategies can be derived.



3 *Exemplary temperature profile over the component geometry with selected measuring points.*

The project

Within the framework of the EU research program AI-NET, research is being conducted into technologies that will accelerate the digital transformation in Europe. In a number of industry-led projects, the technology fields of communication networks and technologies for 5G and, prospectively, 6G, user-oriented data centers and artificial intelligence (AI) are being addressed. The German project consortium of "AI-NET-ANIARA" focused on the application fields of sensor systems and production technologies.

The "AI-NET-ANIARA" project was funded by the German Federal Ministry of Education and Research (funding number 16KIS1275) and is part of the EU research program AI-NET.

Project partner

- Ericsson AB (project coordination), Arctos Labs AB, Chalmers University of Technology, Enoc System AB, Royal Institute of Technology, Kungliga Tekniska Högskolan, Logical Clocks AB, Qamcom Research and Technology AB, RI.SE Research Institutes of Sweden AB, Systemair AB, Univrses AB, Delta Electronics (Sweden)
- King's College London, HAL Robotics, Konica-Minolta (Great Britain)
- Opel Automobile GmbH, Technische Universität Braunschweig, Fraunhofer IPT, IconPro GmbH (Germany)

Contact

Anna Schott M.Sc.
Phone +49 531 2155-674
anna.schott@ist.fraunhofer.de

Martin Rekowski M.Sc.
Phone +49 531 2155-642
martin.rekowski@ist.fraunhofer.de

Optical systems and applications

Optical and electrical functional coatings: Successes, digitalization and visions for the future

What are the focal points of the department?

The department primarily focuses on the field of coating technologies for optical and electrical applications as well as the simulation of low-pressure processes and particles. With optical coatings, we address high-precision multilayer interference filters for various industrial applications. Functional coatings such as separating diaphragms for hydrogen or magnetic sensors form a further focus. The PIC-MC (Particle-in-Cell-Monte-Carlo) method for the simulation of plasma coating processes continues to be an important pillar of support."

What were the highlights in the reporting year?

In the current reporting year, we continued to research and develop precision optical coatings and were able to thereby achieve exciting new results. Several coating runs have now been carried out using our new OPTA-X sputtering system, including the deposition of notch filters with more than 500 layers and a layer thickness of more than 50 µm. The "Rainbow" project focused on the development of extremely steep gradient filters in which the position of a bandpass shifts in dependence on a spatial coordinate. We thereby succeeded in realizing a number of different gradients on one substrate with high precision (see Figure on the left). A further focus of our work was formed by the digitalization of process sequences. Most of the coating systems at the institute are already integrated into the database system, in which data are continuously collected for further evaluation and analysis."

What are the plans for the future?

Coating technology for precision optical coatings will continue to be developed further. As a result, new applications will be addressed, such as components for fluorescence analysis, machine vision or laser protection. New strategies for the monitoring of optical coatings are already being implemented and will be realized in the near future. In the field of electrical functional layers, hydrogen research is being intensified within the scope of the two new research projects "PureBio" and "HySecunda". One aspect of these projects is the creation of hydrogen separating diaphragms that can be used to convert pre-purified hydrogen into a high-purity form.

In the area of coating-process simulation, we will focus on further refining the modeling of plasma-supported processes in the future and, furthermore, will continue to work on the implementation of a user interface for the PIC-MC software in order to make the software accessible to a wider range of users. The PALADIN simulation software for the simulation of microparticles will continue to be expanded and investigated with regard to further application possibilities. In the "6Demo" project, for example, the dispersion behavior of emission-laden airflow is being analyzed with the aim of reducing particle pollution in mechanical machining processes."

Optical bandpass filter with a very steep gradient in the x-direction (from bottom to top in the illustration). The filter consists of more than 200 layers and has a thickness of approx. 20 µm.

#WeKnowSolutions

- Development of precision optical coatings from prototypes to pilot series
- Large-area optical, electrical and magnetic coatings
- Conducting of simulation studies by means of PIC-MC
- Studies for the simulation of dust exposure and particle movement in rooms and on surfaces by means of PALADIN
- Solutions for the controlling of coating processes, e. g. with the aid of the MOCCA+® monitoring software
- Production of large-area TCO coatings

Contact

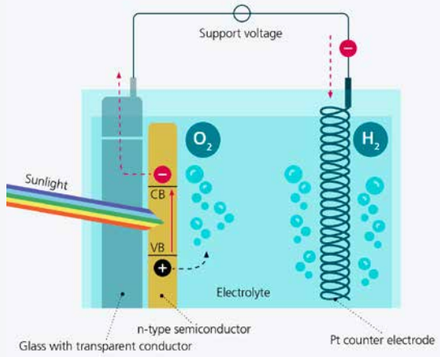
Dr. Michael Vergöhl
Phone +49 531 2155-640
michael.vergoehl@ist.fraunhofer.de

From research

Hydrogen production by means of sunlight

Hydrogen is considered to be one of the most promising energy carriers for a sustainable and environmentally friendly energy supply. In this context, the utilization of sunlight as an energy source for hydrogen production is constantly gaining in importance. Direct solar water-splitting makes it possible to produce hydrogen by means of sunlight. It represents an alternative to the conventional method using photovoltaics and a downstream electrolysis unit. Within the framework of the Fraunhofer joint project "Neo-PEC", this technology was evaluated and further developed and a hybrid demonstrator was constructed.

1



PEC half-cell structure with an n-type photoanode that is conductively connected to a platinum counter electrode. In this hybrid variant, a low auxiliary voltage is generally still required, provided e.g. by a solar cell.

2

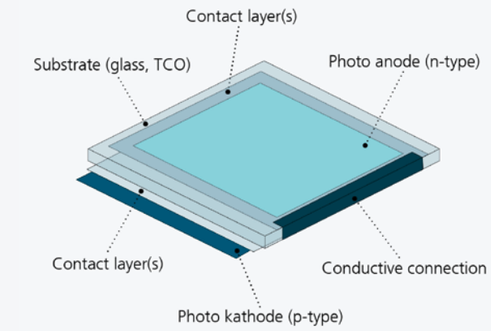


Illustration of a tandem cell consisting of an n-type and a p-type semiconductor on a contact layer and a transparent conductive oxide (TCO) for the creation of oxygen (anode) and hydrogen (cathode).

Solar water-splitting

In direct solar water-splitting, a semiconducting material is brought into direct contact with an aqueous electrolyte. Through illumination with sunlight, energetically enhanced electrons and so-called holes are generated within the material. These reach the interface with the aqueous electrolyte where they trigger the chemical reactions for hydrogen and oxygen formation that are known from classic electrolysis.

In the simplest case, such a system can be realized using e.g. titanium oxide particles in an aqueous solution. The resulting gases reach the surface and can be collected there. The disadvantage of this procedure, however, is that oxyhydrogen gas is formed, an explosive mixture of oxygen and hydrogen.

Project approach

The aim of the "Neo-PEC" project was the development, in collaboration with the Fraunhofer Institute for Ceramic Technologies and Systems IKTS and the Fraunhofer Center for Silicon Photovoltaics CSP, of a new type of PEC module that will enable the cost-effective and clean creation of green hydrogen in the future and, consequently, a decentralized hydrogen supply.

The degree of efficiency should thereby be significantly increased, whilst the disadvantages of simple particulate systems and other very complex systems should be avoided and the costs significantly reduced.

The chosen approach (see Figures 1 and 2) offers a simple structure and the advantage that hydrogen and oxygen can be produced and captured separately from one another, thereby avoiding the formation of oxyhydrogen gas.

The Fraunhofer IST contributed its expertise in the cost-effective large-area coating of high-quality semiconductor absorbers by means of physical vapor deposition (PVD). Initially, transparent carrier plates were coated with differing semiconducting materials that absorb sunlight, in order to produce hydrogen and oxygen.

Over the course of the project, the process was continuously optimized. The finished plates were subsequently integrated into a module with feed lines and discharge lines for the aqueous electrolyte and the resulting gases in order to demonstrate the entire system on a pilot-plant scale.

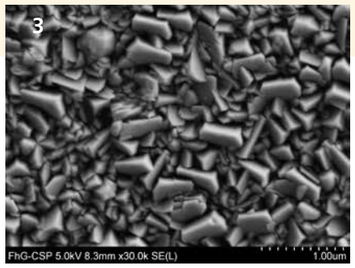
Results

Within the framework of the project, the Fraunhofer IST developed and optimized various semiconductor materials by means of sputtering processes:

- n-type semiconductors: $SrTiO_3$, TiO_2, $WMoO_3$, WO_3
- p-type semiconductors: $AgRhO_2$, $CuCrO_2$

Figures 3 to 5 exemplarily illustrate different morphologies of WMoO3, which were deposited at varying working points and examined by the Fraunhofer CSP with regard to their microstructure.

3



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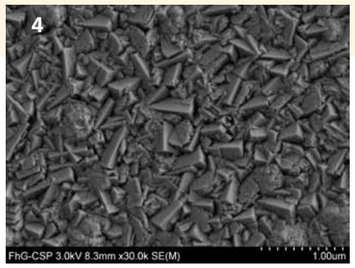

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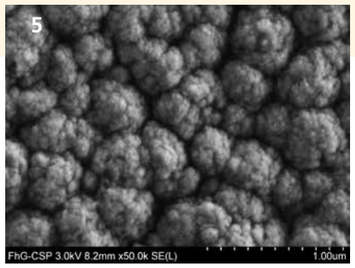


SEM images of WMO_3 photoanode manufactured at different working points. Photocurrent jphoto(2V vs. RHE): 0.935, 0.762 and 0.432 mA/cm², layer thicknesses: 1.88, 1.39, 1.86 µm, from left to right.

[1]Cheng et al., Monolithic Photoelectrochemical Device for Direct Water Splitting with 19% Efficiency, ACS Energy Lett. 3 (2018), 1795–1800.

Neo-PEC

For the evaluation of the quality, the voltage-dependent photocurrent was used, which was measured in the so-called half-cell configuration at the solar-simulator test station and which is a direct measure of the hydrogen production. 1 mA hereby corresponds to 18.8 mg hydrogen. This was used to produce a segmented photoanode on a pilot-plant scale of 30 x 30 cm^2, with which a photocurrent of 150 mA at 2 V auxiliary voltage could be achieved (see Figure 7). Final work is currently being carried out on the integration of the photoanode and an adapted solar cell for the auxiliary voltage into the final PEC module.

Outlook

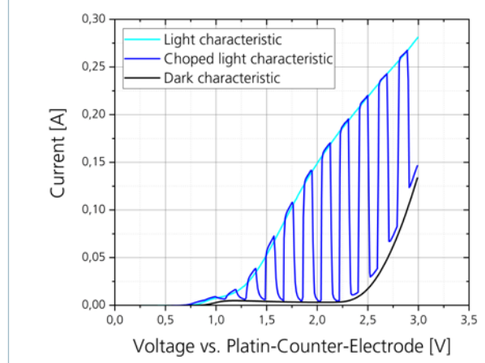
Within the framework of the project, it was possible to further expand the Fraunhofer IST's expertise in the development and realization of p-type and n-type semiconductors by means of the sputtering process and to demonstrate it in solar water-splitting. Prospectively, it will be necessary to further improve the quality of the photoanode (or cathode) in order to increase the hydrogen yield and to achieve a transition to semiconductors with a band-gap-related higher yield. In cooperation with partners, the Fraunhofer IST plans to continue its involvement in the development of efficient PEC modules and, consequently, to provide a further contribution towards the energy transition.

The project

The project Neo-PEC – Novel, large-area tandem PEC modules with dual Schottky junction for hydrogen production was funded internally by the Fraunhofer-Gesellschaft. It is a cooperation with the Fraunhofer Institute for Ceramic Technologies and Systems IKTS (production and provision of sputtering targets) and the Fraunhofer Center for Silicon Photovoltaics CSP (module construction and photoelectric characterization).

Demonstrator module with segmented photoanode for the measurement of photocurrent and hydrogen production in the solar simulator at the Fraunhofer CSP.

6



7

Bias-voltage-dependent photocurrent (brightness characteristic) of the segmented photoanode under illumination with artificial sunlight. Measurement against titanium counter electrode in 1 molar perchloric acid ($HClO_4$), pH value < 2. The active area covers 455 cm^2.

Contact

Dr. Stephan Ulrich
Phone +49 531 2155 618
stephan.ulrich@ist.fraunhofer.de

Interfacial chemistry and adaptive adhesion

Innovations through optimized interfaces

#WeKnowSolutions

- Development of sustainable process chains with electro- and plasma-chemical processes
- Development of sources and their integration into customer systems
- Processes for the treatment and coating of complex three-dimensional components
- Characterization of interfaces and process evaluation
- Adhesion control for the optimization of recycling processes

What are the focal points of the department?

In the Interfacial Chemistry and Adaptive Adhesion department, we develop customer solutions that range from the defined wetting of surfaces and the targeted control of adhesion to debonding-on-demand in recycling processes. The optimal design of the interface and the adaptation of the system technology is thereby a decisive success factor and our key to innovation. We utilize combination processes from plasma functionalization, wet-chemical processes and electroplating technology in order to be able to fulfill quality requirements and specifications from sectors such as medical and pharmaceutical technology, safety applications and mobility and, as a result, to develop sustainable products with efficient processes for our customers."

What were the highlights in the reporting year?

The importance of interfaces can be seen in the department's current research projects. In the "COOLBat" project, we have developed new types of heat-conducting mats consisting of galvanically metallized porous polymers for battery systems in electric vehicles. For security cards, we researched an adhesive-free, low-temperature joining process for bio-based polymer films based on plasma polymer layers in the "BioElse" project. At the end of the card's life, the polymer films can be separated via a targeted trigger and then recycled. In collaboration with the Center of Pharmaceutical Engineering PVZ, we were able to develop coatings that significantly reduce the adhesion of particles to the surfaces of inhalers, for example."

What are the plans for the future?

The circular economy will play an increasingly prominent role in future projects. For example, we will be conducting more research into the development of sustainable surfaces and materials for applications in areas such as medical technology and mobility. Amongst other things, we are working on re-designing the interiors of patient rooms of the future or autonomous vehicles. We thereby want to address questions such as how dirt-repellent functions on the basis of PFAS-free materials (per- and polyfluoroalkyl substances) can be realized, which efficient and sustainable cleaning and preparation processes can be used that are simultaneously both efficient and sustainable, or which mechanical, chemical or biological recycling strategies are possible under the aspects of ecological and economic evaluation."

Selectively functionalized surface for the formation of "hanging drops" for 3D cell models.

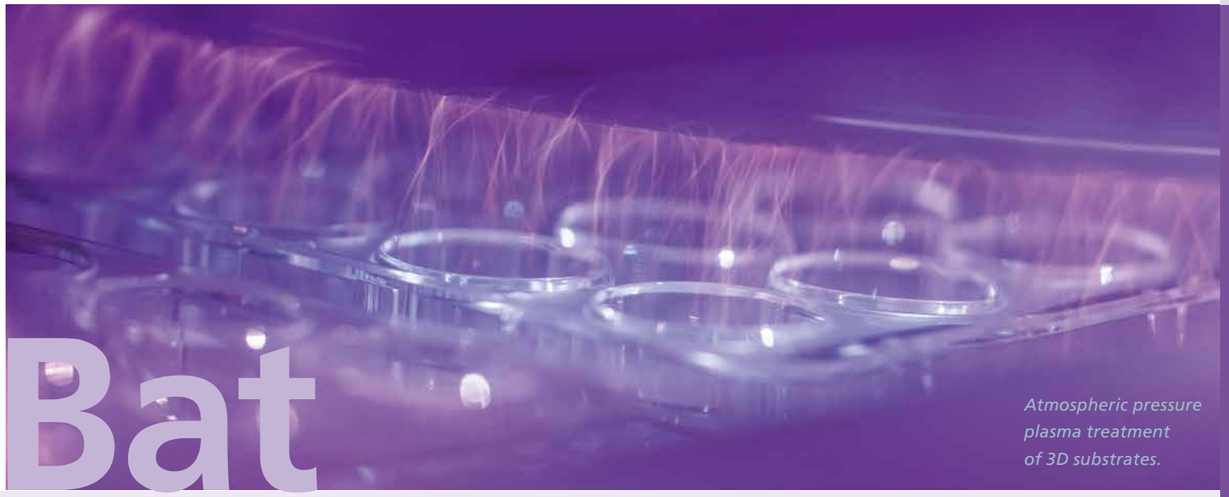
Contact

Prof. Dr. Michael Thomas
Phone +49 531 2155-525
michael.thomas@ist.fraunhofer.de

From research

CO_2-saving lightweight-construction solutions for next-generation battery housings

COOLBat



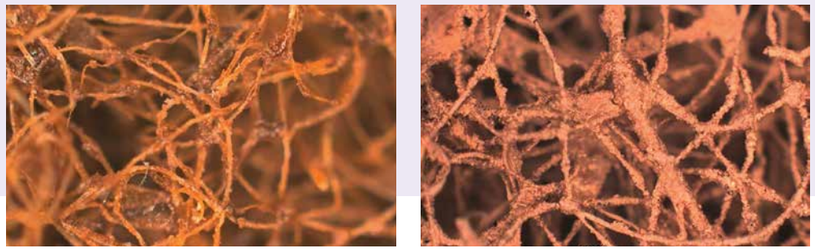
Atmospheric pressure plasma treatment of 3D substrates.

In order to achieve future climate targets, CO_2 must be continuously reduced along the entire value chain and throughout the entire product life cycle. Innovative lightweight-construction materials and material combinations, manufacturing technologies and multifunctional structures can provide a significant contribution towards achieving these goals and, consequently, to the strengthening of Germany as a location for innovation.

The COOLBat project focuses on the development, optimization and scaling of lightweight-construction materials and technologies for battery systems, e. g. in electric vehicles. At the Fraunhofer IST, we are working on replacing environmentally harmful, expensive and barely recyclable thermally conductive pastes, which are utilized in the cooling of battery cells, with so-called thermally conductive mats. With the aid of a REACH-compliant procedure based on atmospheric-pressure plasma and electrochemical processes, thermally conductive mats are produced from natural-fiber foams with modified surfaces. Furthermore, the environmental impact of the battery housing and its components is being investigated at the Fraunhofer IST. By means of a Life Cycle Assessment (LCA), all emissions over the entire life cycle of the housing are analyzed - from material extraction, through production and the use phase, and on to recycling. As a result, insights can be gained into which concepts could also be promising for industrial use in order to make the battery housing more environmentally friendly.

Through the reduction in the number of individual systems and the application of integral manufacturing processes, it is possible to reduce cost- and mass-intensive interfaces and energy-intensive joining technologies. With regard to the thermally conductive mats, the result is a flexible, thermally conductive lightweight-construction component for integration into the battery housing. Its manufacture is performed using cost-effective, resource-conserving and environmentally friendly materials and production processes. As a result, energy can be saved in the manufacturing and assembly process, and CO_2 emissions can be reduced during the use phase.

Coconut mat made from coconut fibers with copper coating.



LSM image of coconut fibers without (left) and with copper coating (right).

The project

CO_2-saving lightweight-construction solutions for next-generation battery housings

Duration

05/01/2021 - 06/30/2024

Project partners

- Fraunhofer Institute for Machine Tools and Forming Technology IWU
- Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM
- Fraunhofer Institute for Wood Research, Wilhelm-Klauditz-Institut, WKI
- Auto-Entwicklungsring Sachsen GmbH
- Basdorf, Lampe und Partner GmbH
- Compositence GmbH
- INVENT GmbH
- iPoint-systems GmbH
- LXT Group GmbH
- MID solutions GmbH
- Synthopol Chemie Dr. rer. pol. Koch GmbH & Co. KG
- Tigres GmbH
- TRIMET Aluminium SE
- Daimler AG

Funding body

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Contact

Rowena Duckstein M.Sc.
Phone +49 551 3705-619
rowena.duckstein@ist.fraunhofer.de

Diamond-based systems and CleanTech

Diamond-based systems for high efficiency, performance and reliability

What are the focal points of the departmen?

The technological focus of the department is formed by hot-wire CVD (chemical vapor deposition), which enables the production of crystalline diamond and silicon layers on large surfaces and complex geometries. In the field of diamond coatings, the technology enables, for example, the production of extremely homogeneous crystalline diamond layers on large surfaces, sub-micrometer coatings on functional surfaces and wear-resistant coatings on complex geometries. As a result, the high demands placed on high-performance components and industrial tools – such as extreme hardness, durability, biocompatibility and chemical inertness – can be met. Amongst other things, we thereby introduce diamond – the hardest material in the world – into our customers' applications by means of our coating technology and develop, in collaboration with the customers, unique products.
This is complemented by the application of atomic layer deposition (ALD), with which nanoscale, low-defect and highly conformant layers can be deposited. By combining both technologies, we are able to fulfil a wide range of requirements and further develop them for our customers' applications, such as the highly conformant functionalization of diamond and silicon structures by means of ALD layers in sensor applications."

What were the highlights in the reporting year?

We were particularly pleased that we were able to diamond-coat the internal geometries of tools such as drawing dies with high aspect ratios by means of CVD using a special system setup and to successfully extend the service life in wire production. In addition, we were able to reduce the roughness of diamond coatings with a new interlayer system, thereby significantly increasing their suitability for sheet-metal forming.

With our expertise in the provision of electrochemically generated disinfectants, we were able to contribute towards the development of a preclinical healthcare platform that can enable mobile medical care, even in remote areas of the sub-Saharan region. An expansion of our S-ALD coating system for thermal local atomic layer deposition to include a linear evaporator unit, developed in-house, will enable research into complex electron contact systems for perovskite silicon tandem solar cells in the future."

What are the plans for the future?

The supply and sustainable utilization of energy and raw materials are crucial for the future of manufacturing companies. Through new and further developed systems, coating technologies and processes, we are working in collaboration with our partners to significantly reduce the material and energy requirements and, consequently, the production costs of diamond coatings and to increase the compatibility of our coatings and processes with, amongst other things, new base materials, in order to make the advantages usable in new applications. In a recently launched project, we are researching AI-based inspection systems for the automated detection of defects and production errors during delivery, pre-treatment, coating and post-treatment. With the latest spin-offs in Canada and South Africa, we are also strengthening our internationalization for the benefit of our local partners."

Contact

Dr. Volker Sittinger
Phone +49 531 2155-512
volker.sittinger@ist.fraunhofer.de

#WeKnowSolutions

- Development of application-specific layer systems for diamond- and silicon-based applications
- Optimization of economic efficiency through large batch volumes and/or high-rate processes
- Development of components for the applied technologies
- Coating-oriented component design and material selection for diamond tools

Hot-wire CVD system for the production of diamond coatings on large surfaces up to 0.5 x 1 m.

The PreCare platform in the field test: The mobile care unit can also be used to reach rural areas to provide healthcare services on site.

From research

Health care for everyone and everywhere

In rural regions of Africa, poor accessibility is often a major obstacle to providing people with comprehensive medical care. In the "PreCare – Health Care for Everyone and Everywhere" project, an international team from two Fraunhofer Institutes and the Stellenbosch University is developing cost-effective modular solutions for pickups that will enable preclinical examinations, tests, and vaccinations to be carried out even in less accessible areas.

Creating perspectives prospects for Africa in Africa is a task of global interest for humanitarian and strategic economic reasons. The challenges are immense: more than 1.5 million people die every year in the Sub-Saharan region of Africa alone from the four most common diseases malaria, HIV/AIDS, COVID-19, and tuberculosis[1]. The reasons for this are often a lack of health care and hygiene, especially in remote areas.

At the same time, the people themselves are often very limited in their mobility. As a result, it is often almost impossible to carry out comprehensive examinations for the early detection of diseases, systematic data collection to determine epidemic situations, the implementation and tracking of nationwide vaccination, medication and education campaigns, and direct contact between patients and healthcare professionals.

The challenge is therefore to develop medical supply units that can penetrate very deep into the interior of the country, i.e. have the appropriate off-road capability, and can also be produced in large numbers at low cost..

The care platform

The mobile care platform developed by researchers from the Fraunhofer Institutes for Surface Engineering and Thin Films IST and for Solar Energy Systems ISE together with Stellenbosch University as part of the PreCare project funded by the Fraunhofer Future Foundation consists of a cabin that contains modular supply elements such as a water treatment plant, on-board disinfectant production, a refrigerator and a telecommunication unit, and can also accommodate medical devices, medical substances and test equipment. A photovoltaics generator in combination with a backup battery provides the entire unit with a permanent, self-sufficient power supply. A laptop with satellite link and Bluetooth-enabled examination devices, such as a blood pressure monitor or electrocardiogram (ECG), will enable patients to receive telemedical consultations from medical professionals on site and thus contribute to better health education in the future.

Nine-month test phase in collaboration with local NGO

The first prototype of the mobile care platform was handed over to the non-profit organization Rhiza Babuyile in March 2023 for a nine-month test phase, where it was used in various centers for the disabled in the municipality of Daantjie (Mpumalanga region, South Africa). In addition to monitoring vital signs, including blood pressure measurements and ear, nose, eye and throat examinations, HIV tests were primarily carried out as part of general health education and consultation.

Improvement in the general state of health of the patients cared for

The evaluation of the treatments and examinations shows that around 120 patients per month made use of the so-called "PreCare" services. As a result, the health conditions in the affected centers were measurably improved in the first eight months of the platform's operation:

On the one hand, patients with chronic illnesses took the necessary medication more reliably, and on the other hand, hygienic conditions were significantly improved thanks to access to disinfected water from the "PreCare" platform, thus reducing complications.

Outlook: Near-series testing planned in Namibia

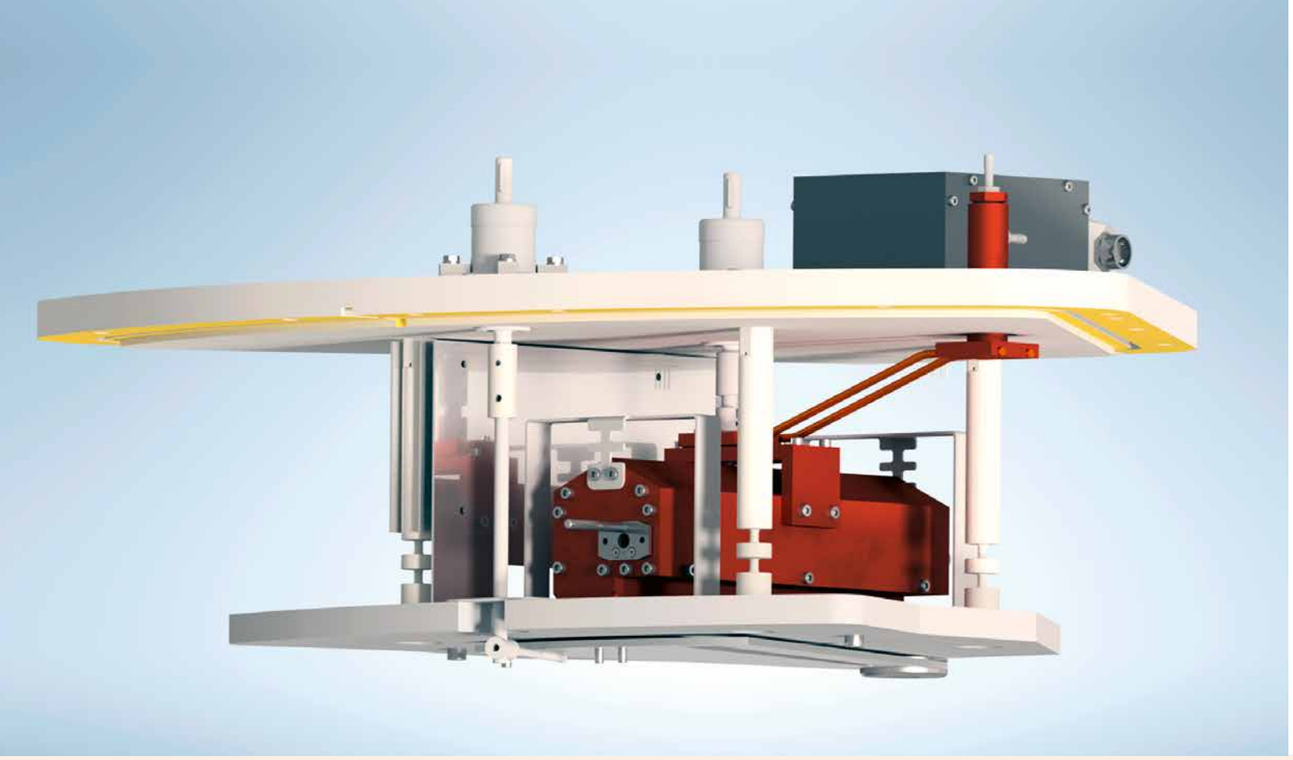
After consultation with all parties involved the evaluation phase of the platform, which was originally planned until the end of 2023, will be extended by a further six months up to and including June 2024 in order to test the prototype further in the field and incorporate the findings into the development and design of a second prototype that is closer to series production. At the same time, another NGO, Mudiro e.V., has been secured for the future trial operation of a second platform in Namibia. This platform will be manufactured entirely in Africa and is scheduled to go into operation in April 2024 as part of a one-year program for the early detection and prevention of cervical cancer.

This project was funded by the Fraunhofer Future Foundation.

Contact

Dipl.-Ing. (FH) Frank Neumann
Phone +49 531 2155-658
frank.neumann@ist.fraunhofer.de

[1]Bell, David, Hansen, Kristan Schultz, 2021, "Relative burdens of the COVID-19, malaria, tuberculosis, and HIV/AIDS epidemics in sub-Saharan Africa" American Journal of Tropical Medicine and Hygiene, Vol. 105, No. 6, pp. 1510-1515, 0002-9637, doi10.4269/ajtmh.21-0899.



Design of the evaporator system.

From research

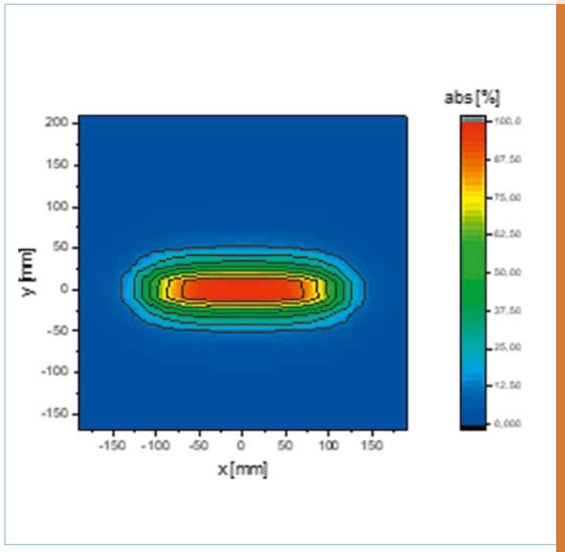
Sustainable, highly efficient perovskite-silicon tandem solar cells

In order to slow down climate change, a huge expansion of renewable energies is necessary. The lowest costs for electricity generation are now provided by photovoltaics. Currently, however, the cost drivers are still the required storage technologies. In order to reduce overall costs, it is therefore necessary to further increase the efficiency of cell technology. A promising solution is offered by tandem solar cells based on silicon technology. With the low-cost silicon cell as a bottom solar cell and a top cell consisting of a perovskite structure, the solar spectrum of the sun can be better exploited. It is expected that within a few years, it will be possible to achieve significantly higher efficiencies of approx. 40 % and, as a result, considerably higher yields per utilized area.

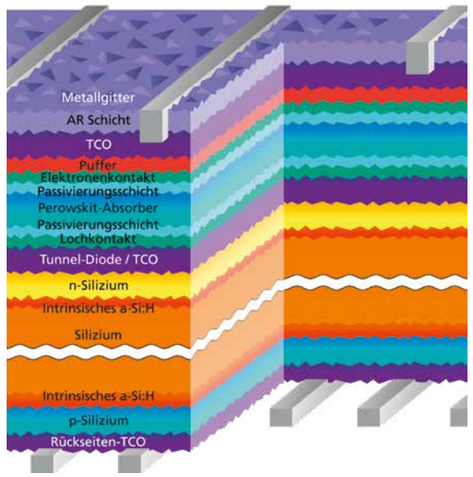
Within the framework of the Fraunhofer flagship project MaNiTU, the Fraunhofer IST has developed and investigated a multitude of necessary functional and contact layers as well as the associated system technology, and has scaled them up to areas of 210 mm², which corresponds to today's wafer sizes.

Particular challenges in the coating of perovskite absorber material

At more than 25 %, perovskite solar cells now achieve similar levels of efficiency to those of silicon solar cells. The perovskite absorber material, however, has a complex crystal structure and consists to some extent of organic components, which makes it sensitive to further coating. In addition, the tandem cells themselves also have a very complex structure. They consist of a multitude of wafer-thin functional and contact layers that are deposited under, between and on top of the two absorbers.



Layer distributions of selected evaporator geometries can be determined in advance with the aid of PICMC simulations.



Structure of a perovskite-silicon tandem cell with Si-HTJ bottom cell.

These layer systems are subject to stringent requirements that impede the upscaling and further optimization of the technology developed in the laboratory. The layers must be optically transparent, i.e. they must exhibit no or only minimal absorption. Moreover, the electrical properties must be adapted in such a way that the charge carriers reach the contacts. Furthermore, the interfaces must be free of defects across the entire surface. As the perovskite cell is temperature-sensitive, only temperatures below 100 °C may be used in the manufacture of the front contact system.

New technologies and processes for the coating of perovskite absorber material

For the development of functional layers for silicon heterostructure solar cells (Si-HTJ) and the coating of the perovskite absorber material, the Fraunhofer IST is able to draw on extensive experience in the production of functional and contact layers for S-HTJ and amorphous/microcrystalline silicon tandem solar cells. In the current project, selective charge-carrier layers suitable for large areas are being produced, as well as buffer and passivation layers and transparent conductive oxides (TCO). For the development of the electron contact system, a novel high-rate S-ALD hybrid system is being deployed.

The evaporator system is constructed in the hybrid area of the S-ALD.

S-ALD hybrid

This system can be used to produce tunnel layers on the basis of metal oxides on the perovskite absorber, as well as the subsequent electron contact layer by means of linear-evaporator technology developed in-house and the subsequent passivation layer.

The ensuing deposition of the front contact is then performed by means of a sputtering process. For the optimization of the front contact, the Fraunhofer IST first uses a serial co-sputtering process established at the institute. In the next step, the transparent front contact layers are deposited with the aid of the metallic alloy target with the previously determined optimum composition. Both technologies enable a high-throughput process.

A step towards a high-performance European photovoltaic industry

With the help of the technologies applied and developed at the Fraunhofer IST, the respective individual processes can be coordinated and optimized within the entire process chain. The technology of the Fraunhofer IST is transferable to the cell surfaces and industrial process chains required by the industry and allows the consideration and optimization of the entire solar cell stack in terms of efficiency and costs. A transfer to the plant constructors and also the cell manufacturers could sustainably improve their competitiveness and help to re-establish a strong European photovoltaic industry.

Outlook: Further efficiency increase and industrial utilization

As a result of the work carried out by the Fraunhofer consortium, efficiency levels of over 30 % have now been achieved for tandem solar cells, and methods for scaling-up the surfaces have been identified along with the potential for a simultaneous increase in efficiency. In order to involve industry in further development, the first collaborative workshop took place in October 2023. In addition, the first joint funding applications with industrial partners have been submitted in order to consolidate and industrially utilize the achieved results in the future.

The project

Within the Fraunhofer flagship project MaNiTU, five Fraunhofer institutes are pooling their globally unique portfolios of expertise. In addition to proven expertise in the field of solar cells and sustainability assessment, this also includes profound knowledge and experience in theoretical and experimental materials science, in process development and in the characterization of individual materials through to entire systems. The aim is to achieve technological leadership in the field of sustainable, highly efficient tandem solar cells.

Contact

Dr. Volker Sittinger
Phone +49 531 2155-512
volker.sittinger@ist.fraunhofer.de

Application Center

Plasma particle technology

What are the focal points of the departmen?

The Application Center's core technological expertise lies in low-energy plasma spraying and atmospheric plasma-enhanced chemical vapor deposition (PEVCD). This process is used in order to coat thermally sensitive objects such as thin films, membranes or papers. Our focus thereby lies on the development of products with integrated current conduction and sensors, the coating of membranes for the hydrogen and battery industry, tribological coating systems and barrier coatings. Further key areas are powder coating and the medical plasma permeabilization of biological samples."

What were the highlights in the reporting year?

In line with the German government's hydrogen strategy, the ScaleH2 project of the BMBF's HyGATE funding initiative has been launched. Within the framework of the project, we are working closely with partners from Germany and Australia, including ATCO, the University of New South Wales (UNSW) and the University of Technology Sydney UTS, the Fraunhofer Research Institution for Energy Infrastructures and Geothermal Systems IEG, the Institute of Energy and Process Systems Engineering at the TU Braunschweig, Whitecell-Eisenhuth GmbH & Co. KG and, as associated partners, Salzgitter AG and Uniper SE. The aim of the project is the utilization of scalable PEM electrolysis stacks with innovative materials in order to create renewable hydrogen in a cost-efficient way."

What are the plans for the future?

In a world that is increasingly having to face the challenges of sustainability and environmental protection, the focus lies on the development and implementation of resource-conserving plasma treatment and coating technologies. Our aim is to promote the production of recyclable, bioeconomic materials. This includes, for example, the use of biological starting materials or the reduction of fluorine-containing substances in coating technology. The challenge thereby lies in the transfer of these techniques to industry in order to achieve sustainable materials management."

Plasma-sprayed temperature sensors.

#WeKnowSolutions

- Low-energy plasma spraying
- Atmospheric plasma-enhanced chemical vapor deposition
- Development of plasma sources, device and system construction
- Powder coating and powder modification
- Plasma permeabilization

Contact

Prof. Dr. Wolfgang Viöl
Phone +49 551 3705-218
wolfgang.vioel@ist.fraunhofer.de

From research

Biomimetic plasma polymers for the functionalization of paper

BioPlas4Paper

Paper is an integral part of our daily lives in so many ways, one example being the packaging industry. However, in order to fully exploit the potential of the material and to thereby replace, for example, conventional plastic packaging and open up new fields of application, the service life and performance of paper products must be increased. The major challenges here are presented by the temperature sensitivity of the paper, its surface irregularities and the chemical diversity of the material.

In order for homogeneous, functional and adhesive layers to be created on paper, meticulous coordination of the individual parameters is required. Within the framework of the BioPlas4Paper project, a novel plasma-source concept was developed with which a reproducible process environment can be created under atmospheric pressure that reduces the influence of ambient air to a minimum, therefore achieving homogeneous, reproducible coating results.

This innovative approach incorporates unused plant substances such as oils and extractive matter – without competition to food production – into the coating process and enables the hydrophobization of paper through the application of atmospheric-pressure plasma technology (PECVD, plasma-enhanced chemical vapor deposition).

Here, it is essential that the plant substances or extractives exhibit a high proportion of unsaturated fatty acids, as these are capable of polymerization processes in interaction with the reactive species of the plasma.

The added social value of the development lies in the promotion of sustainability and the bioeconomy through the efficient utilization of renewable raw materials, which leads to a CO_2-neutral, value-adding usage of paper.

The BioPlas4Paper project is therefore supporting the transition to a resource-efficient economy, is improving the ecological balance and, by striving for long-term security of supply with reduced dependence on fossil resources, is also addressing challenges such as resource scarcity.

The project

Biomimetic plasma polymers for the functionalization of paper

Duration

05/01/2021 - 06/30/2024

Project partners

- The Technical University of Darmstadt, specialist department: Macromolecular Chemistry and Paper Chemistry
- Johann Heinrich von Thünen Institute, Federal Research Institute for Rural Areas, Forestry and Fisheries

Funding body

FNR – Fachagentur Nachwachsende Rohstoffe

Volume glide discharge on recycled paper.

Contact

Martin Bellmann M.Eng.
Phone +49 551 3705-379
martin.bellmann@ist.fraunhofer.de

#WeKnowSolutions

- Advice on corporate sustainability strategy
- Support in the implementation of the Sustainable Development Goals (SDGs) in your company and derivation of measurable targets
- Early identification of potential in order to increase sustainability
- Detailed analysis of specific sustainability trends
- Support of business processes from the early phase (production planning, product development and procurement) through to the finished product and identification of optimization potentials
- Decision support for the reduction of negative environmental impacts
- Development of tools for the quantification of the product carbon footprint (PCF) and the corporate carbon footprint (CCF)
- Customized learning modules in the area of sustainability and LCE

Sustainability management and Life Cycle Engineering

Sustainability throughout the product life-cycle

What are the focal points of the department?

In the area of sustainability management, we advise companies on the alignment of their strategy, products and processes with the key sustainability goals (Sustainable Development Goals of the UN) relevant to the company and integrating these into business processes and decisions. The ecological, social and economic opportunities and risks of an organization are thereby identified, and measures are developed to manage them. In the area of Life Cycle Engineering (LCE), we develop methods with which sustainability can be measured and, consequently, managed. LCE is an approach aimed at designing products and processes, thereby taking the entire life cycle into account. It provides companies with a tool with which to improve their products through the minimization of environmental impacts, the maximization of resource efficiency and the development of sustainable solutions."

What were the highlights in the reporting year?

The department is involved in large-scale European research projects and various industrial projects that cover all facets of Life Cycle Engineering and sustainability topics. Our projects include, for example, "TranSensus LCA", which aims to define and harmonize a standardized and applied Life Cycle Assessment approach for zero-emission vehicles (ZEV). Furthermore, within the framework of the "HiQ-LCA" project, we are working on the provision of high-quality LCA data for lithium battery production. In order to ensure significant steps towards sustainability, the department also advises industrial partners such as the Friedhelm Loh Group (which we are supporting in the development of a sustainability strategy), Volkswagen and many other companies."

What are the plans for the future?

We will expand projects that focus on sustainable products and processes in industry, and will also consolidate far-reaching collaborations and partnerships. The current focus lies on the mobility sector. In the future, we will also expand our expertise to the chemicals sector and in the area of metal and raw-material extraction. One focus will thereby lie on the circular economy, with which closed material cycles and a resilient value chain can be achieved. The work will not only boost growth, but also promote innovation in order to address industry-specific challenges. The aim is to establish the department as a center of excellence for research and development in the field of sustainability management through the consistent implementation of sustainability practices and standards in companies and the application of novel Life Cycle Engineering approaches."

Contact

Prof. Dr. Stephan Krinke
Phone +49 531 2155-504
stephan.krinke@ist.fraunhofer.de

From research

The sustainable car body of the future

FutureCarProduction

Climate neutrality by 2050 is the declared goal of the automotive industry in order to comply with the German government's climate-protection law. The ecological change – the "Way to Zero" – is to thereby be achieved in a cost-efficient manner. In order to attain the sustainability targets, vehicle concepts need to be rethought above and beyond the powertrain. For electric vehicles, the body is the largest factor for CO_2 emissions after the battery.

Current body production is a complicated process involving the manufacture and assembly of numerous structural elements. As a rule, more than a hundred individually stamped metal parts have to be welded together to form a car body. The application of aluminum gigacasting technology is increasingly establishing itself as a revolutionary solution for an alternative to these conventional methods. This innovative approach reduces the quantity of required components, which leads to cost savings and streamlined production. Other competing material solutions, such as multi-material body structures, also offer potential environmental benefits.

Navigating these rapid developments and making sustainable decisions with regard to the circular economy is a challenge for the automotive industry. One of the problems is the insufficient research on the environmental risks of novel technologies – such as gigacasting – compared to the potential economic benefits and the associated high investments. Within the project network, the Fraunhofer IST is developing a model-based Life Cycle Engineering assessment tool for lightweight structures in the automotive industry that can robustly assess both the current situation and possible future developments.

Our team is therefore contributing towards the development, analysis and evaluation of technologies for sustainable vehicle construction in terms of potential environmental impact and costs, thereby taking performance criteria into consideration. In this way, we are supporting the decarbonization of the automotive industry.

The project
Future Car Production

Project duration
01/01/2023 - 12/31/2026

Project partners

- Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM
- Fraunhofer Institute for Material and Beam Technology IWS
- Fraunhofer Institute for Machine Tools and Forming Technology IWU
- Fraunhofer Institute for Mechanics of Materials IWM
- Fraunhofer Institute for Integrated Circuits IIS
- Fraunhofer Institute for Structural Durability and System Reliability LBF
- Fraunhofer Institute for Casting, Composite and Processing Technology IGCV

The project promotes holistic solutions for the evaluation and development of integral body concepts for sustainable vehicle construction.

Life Cycle Engineering as a solution approach for sustainable vehicle construction.

Contact

Prof. Dr.-Ing. Christoph Herrmann
Phone +49 531 2155-503
christoph.herrmann@ist.fraunhofer.de

Prof. Dr. Stephan Krinke
Phone +49 531 2155-504
stephan.krinke@ist.fraunhofer.de

#WeKnowSolutions

- Quantitative SIMS depth profile analysis of technical surfaces and layers
- Quantitative hydrogen determination in DLC layers or in silicon
- Non-destructive and spatially resolved determination of layer thickness and the composition of thin single- or multiple-layer systems (suitable for layer thicknesses from 0.3 to ~500nm), e.g. thin oxide-layer thicknesses
- Quantitative point analysis of light elements such as B, C, N, O in various materials
- Characterization of material fatigue by means of impact tests (up to 5kN, 1 million load cycles in 5 hours)

The Focussed Ion Beam (FIB) device "Cross-Beam 340" from Zeiss is used for the preparation of local cross sections and TEM lamellae.

Analytics and quality assurance

Analysis of layers and surfaces

What are the focal points of the department?

In the Analytics and Quality Assurance department, we perform complex material, layer and surface analyses for industrial and institutional customers. The focus thereby lies on the application of methods with large analytical devices such as scanning electron microscopy (SEM), electron probe microanalysis (EPMA), energy dispersive X-ray spectroscopy (EDX), secondary ion mass spectroscopy (SIMS), X-ray diffraction (XRD) and focused ion beam (FIB). Amongst other things, these devices are utilized for the failure analysis, the specification of new materials, quality assurance in production, the calibration of standards or the reverse engineering of unknown samples."

What were the highlights in the reporting year?

Within the framework of an exciting job for a large German company, we applied SIMS in order to investigate how deeply hydrogen diffuses into certain magnetic materials and to what extent protective layers can reduce this diffusion. For the Herzog August Bibliothek in Wolfenbüttel, we analyzed mineral particles that were discovered in writings on alchemy that are several hundred years old. During the investigations, we found lead oxides and lead nitrates. A further highlight was the investigation of superconducting coatings that are to be used for quantum computers, and we were also able to successfully conduct extensive characterizations of coatings for electrolysis and fuel-cell technology on behalf of a major German automotive supplier."

What are the plans for the future?

The analysis of the diffusion of hydrogen into materials is to be further expanded. For this purpose, the institute has procured a reactor with which samples can be exposed to an H2 or D2 atmosphere at up to 300 °C and 200 bar pressure. SIMS depth profiling can subsequently be used in order to investigate the H or D distribution in the material over depth. A further focus lies on the possibilities offered through the analysis of lithium-based battery materials. A shuttle is available for this purpose, with which Li containing samples can be transfered into the FIB-SEM, a combination of scanning electron microscope (SEM) and focused ion beam (FIB), without contact with air, in order to be able to examine them without degradation."

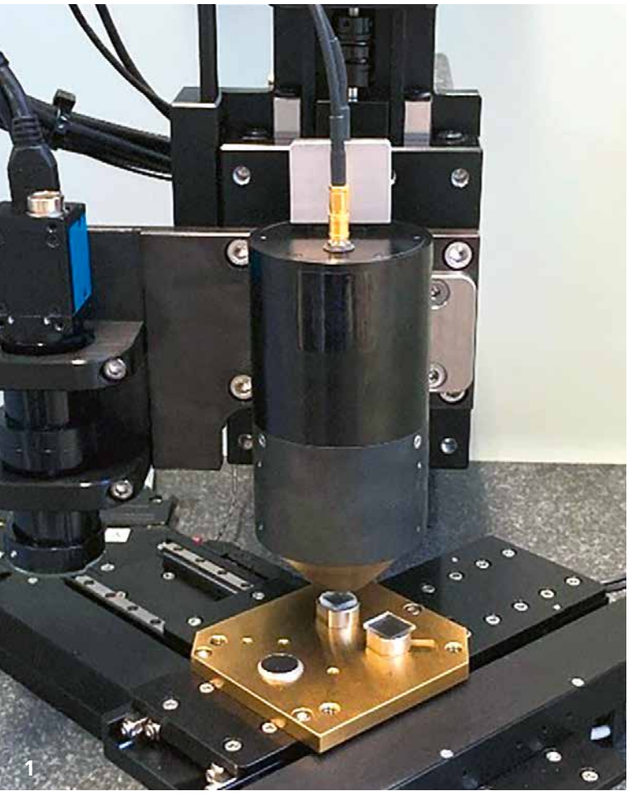
Contact

Dr. Kirsten Schiffmann
Phone +49 531 2155-577
kirsten.schiffmann@ist.fraunhofer.de

From research

Hardness testing on smallest scales: New micro- and nanoindenter at the Fraunhofer IST

In recent decades, the demands placed on materials and their properties have increased enormously: Even for ultrathin coatings, it must be possible to unambiguously determine the hardness and the modulus of elasticity, for example. One common method of hardness testing is nanoindentation, which is also applied at the Fraunhofer IST. The existing range of possibilities at the institute has recently been significantly extended by a new nanoindenter.



The new TS 77 nanoindenter from Bruker.

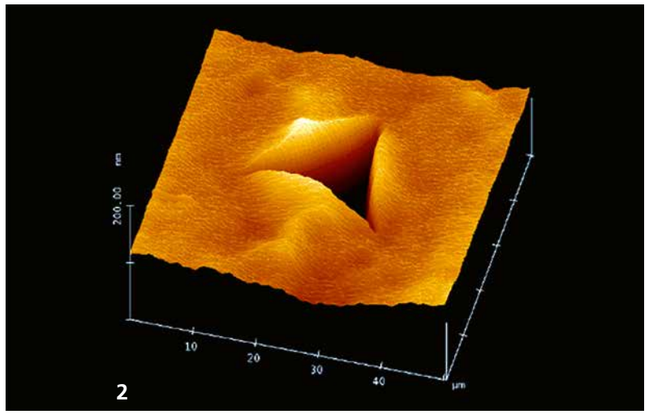
A nanoindenter is deployed in order to determine the hardness, the modulus of elasticity and, if necessary, the viscoelastic properties of materials and thin films. This is performed by pressing a three-sided diamond tip into the surface in a controlled manner whilst continuously recording – with the highest precision – the necessary force and the penetration depth. From the measurement curves, the hardness and the modulus of elasticity of the material can then be determined - in some cases in dependence on the depth.

Extension of nanoindentation

By means of the AFM mode, the surfaces can be imaged topographically both prior to and following indentation with the aid of the diamond tip, thereby enabling, for example, the exact position of an indentation to be verified retrospectively. One special feature is calibration to the hardness of a reference material, which – in contrast to the common calibration to the modulus of elasticity – has the following advantages:

- better reproducibility of hardness values
- better independence of the measurements from the indentation depth
- smaller integral error for hardness and elasticity, even with successive wear of the tip throughout its lifetime.

Furthermore, nano-scratch tests and wear tests can also be carried out with the aid of the scratch module.

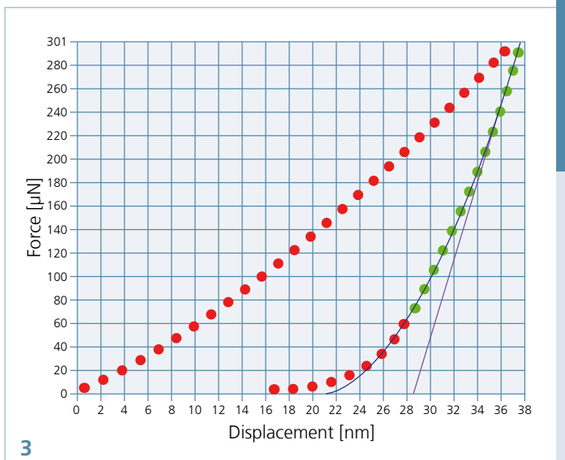


AFM image of an indenter impression.

Advantages of the new device

Compared to the existing capabilities for hardness determination at the Fraunhofer IST, the new indenter device offers a number of advantages:

- With the aid of the new nanoindenter, fully automated measurements of multiple samples can be performed, even with different sample heights and geometries.
- The broad measurement spectrum ranging from high loads (1N) to very small loads (1µN) allows the investigation of solid materials and thick layers as well as very thin layers down to a few hundred nanometers.
- Force-modulation techniques can be applied in order to determine the depth dependence of the hardness or the influence of the substrate - in one single measurement.
- By means of frequency modulation techniques, time-dependent phenomena can be determined, e.g. in polymers (storage and loss modulus).
- Ultrafast measurements of up to 0.6 seconds per measuring point allow the mapping of the hardness and the modulus of elasticity, i.e. the representation of the lateral distribution of non-homogeneous mechanical properties on the micrometer scale. These can be e.g. precipitates in steels, different phases in polymers, multiphase materials, nitriding hardness profiles, etc.



Nanoindenter measurement curve for the determination of hardness and modulus of elasticity..

The application possibilities

Hardness and modulus of elasticity are important parameters for all types of surfaces which are exposed to mechanical stress. These can be, for example, tribological protective coatings on milling cutters, tools, automotive components or machine elements, as well as paints, electroplating coatings, decorative coatings (scratch resistance) and nitrided or borated surfaces, display glass, etc.

Contact

Dr. Kirsten Schiffmann
Phone +49 531 2155-577
kirsten.schiffmann@ist.fraunhofer.de

The Fraunhofer IST in networks

The Fraunhofer-Gesellschaft at a glance

The Fraunhofer-Gesellschaft, based in Germany, is one of the world's leading applied research organizations. It plays a crucial role in the innovation process by prioritizing research in key future technologies and transferring its research findings to industry in order to strengthen Germany as an economic hub as well as for the benefit of society.

As an important customer group, small- and medium-sized companies in particular tap into Fraunhofer's expertise and resources to develop new technologies and maintain their competitiveness. For years, Fraunhofer has been one of the most active patent applicants in Germany and Europe. The research organization is therefore developing an extensive, international patent portfolio in various technology sectors, primarily as a basis for transferring technology through research projects, spin-offs and licensing. In this way, Fraunhofer experts support industry partners from ideation to market launch, and Fraunhofer's interdisciplinary and international collaboration in specific market environments addresses social objectives in important technology areas. Fraunhofer also promotes research into key technologies that are vital for society as a whole by applying specific, interdisciplinary and international collaboration geared to the needs of the market. Examples include technologies for the energy transition, cybersecurity and underlying models for generative artificial intelligence.

Fraunhofer is an attractive and established party for public-private partnerships and also makes a significant contribution to strengthening Germany as a hub for innovation and ensuring its viability in the future. Its activities create jobs in Germany, boost investment effects in the private sector and increase the social acceptance of new technology. International collaboration projects with excellent research partners and companies across the globe ensure that the Fraunhofer-Gesellschaft remains in direct contact with the most prominent scientific communities and economic areas.

Founded in 1949, the Fraunhofer-Gesellschaft currently operates 76 institutes and research units throughout Germany. Its nearly 32,000 employees, predominantly scientists and engineers, work with an annual business volume of 3.4 billion euros; 3.0 billion euros of this stems from contract research, which is divided into three funding pillars. Fraunhofer generates a share of this from industry and license-fee revenue to a sum of 836 million euros. This high proportion of industrial revenue is Fraunhofer's unique selling point in the German research landscape. The importance of direct collaboration with industry and the private sector that this requires ensures a constant push for innovation in the economy, while at the same time strengthening German and European competitiveness.

Another share of contract research revenue comes from publicly funded research projects. The final share is base funding that is supplied by the German federal and state governments and enables our institutes to develop solutions now that will become relevant to the private sector and society in a few years.

Highly motivated employees are the most important factor in Fraunhofer's success. The research organization therefore creates opportunities for independent, creative and goal-driven work. Fraunhofer fosters professional and personal development in order to provide career opportunities for its employees in the private sector and society at large.

The Fraunhofer-Gesellschaft is a recognized nonprofit named after the Munich scholar Joseph von Fraunhofer (1787–1826), who enjoyed equal success as a scientist, inventor and entrepreneur.

Last updated: April 2024

Headquarters of the Fraunhofer-Gesellschaft.

Synergies through networking

Networks within the Fraunhofer-Gesellschaft

Within the framework of its research and development activities the Fraunhofer IST is an integral element of various internal and external networks which are active with diverse focal points in the field of tension between industry, science and politics.

Within the Fraunhofer-Gesellschaft, the Institute has been contributing its expertise in the Fraunhofer Group for Production, which consolidates the specialist knowledge of the Fraunhofer-Gesellschaft for the "production of the future".

Furthermore, the Fraunhofer IST participates as a guest member in the Fraunhofer Group for Light & Surfaces, as well as in various alliances, business sectors, research and competence fields, and networks. The objective is to offer customers and partners optimum solutions for their tasks, including cross-technological options. In addition, the Fraunhofer IST is actively involved in the Fraunhofer Centers for Energy Storage and Systems ZESS and Circular Economy for Mobility CCEM in Wolfsburg. In the High-Performance Center Medical and Pharmaceutical Engineering, which was launched in March 2021, the institute is involved in the development of a platform for research and innovation transfer in patient care.

Fraunhofer Group for
Production

Business Area
Adaptronics

Business Area
Cleaning

Fraunhofer Alliance
SysWasser

Fraunhofer Group
Light & Surfaces

Research Field
Lightweight Design

Fraunhofer Cluster of Excellence
Cognitive Internet Technologies

High-Performance Center
Medical and Pharmaceutical Engineering

Fraunhofer Alliance
Battery

Fraunhofer
POLO®

Fraunhofer Network
Sustainability

Fraunhofer Network
Hydrogen

Fraunhofer Alliance
AutoMOBILE Production

Fraunhofer Competence Field
Additive Manufacturing

Fraunhofer Network
Simulation

Fraunhofer
AVIATION & SPACE

Fraunhofer Center
Circular Economy for Mobility CCEM

Fraunhofer Center for
Energy Storage and Systems ZESS

#WeKnowProduction

Fraunhofer Group for Production

The Fraunhofer Group for Production was founded in 1998 as part of the Fraunhofer-Gesellschaft, the largest organization for application-oriented research in Europe. Today, 13 Fraunhofer institutes and establishments pool their expertise within this group, and offer innovative and sustainable system solutions from the broad field of production technology and logistics for German and international companies.

The Fraunhofer Group for Production focuses on the optimization of the entire value chain, thereby utilizing the latest findings from the disciplines of production science, engineering and computer science as a basis. This enables close and interdisciplinary collaboration between the research institutes and industry, through which the production methods of tomorrow can be designed. The Group offers a wide range of technologies, services and infrastructure in order to equip companies for the challenges and opportunities of future production.

The group in figures

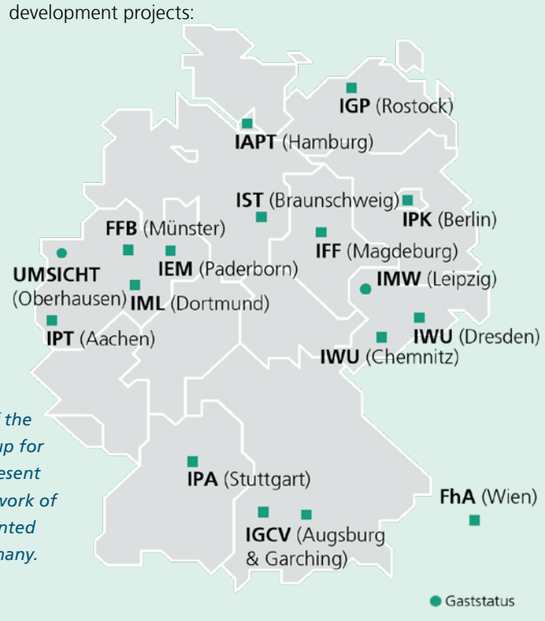
Operating budget[1]: 379 million Euro

Economic revenue[2]: 30,3 %

Employees[3]: approx. 3000

Member institutes

As a production-technology network, the consolidated expertise of the member institutes encompasses all areas along the value chain and is constantly being expanded, in an application-oriented manner, through a wide range of research and development projects:



The institutes of the Fraunhofer Group for Production represent the leading network of application-oriented research in Germany.

[1]Budget 2024 / [2]Result 2023 / [3]2023 (sci./techn./adm. personnel)

Competency portfolio

As a production-technology network, the consolidated expertise of the member institutes encompasses all areas along the value chain and is constantly being expanded, in an application-oriented manner, through a wide range of research and development projects:

- **Production Machinery and Facilities**
  This includes factory planning as well as competences in the field of machine tools and robot systems through to maintenance.
- **Manufacturing Technologies and Process Technologies**
  All competencies in the area of manufacturing technology, in particular in classical and additive manufacturing, are consolidated. Process and surface technologies also form focal points in the Group for Production.
- **Product Development**
  The Group offers integrative solutions in the areas of systems-, software- and virtual-based engineering.
- **Production Control, Automation and Measurement Technology**
  Through smart sensor and plant networking, processes can be automated, whilst the utilization of AI and digital assistance systems enables them to be designed efficiently.
- **Business and Value-Added Management**
  The Group for Production provides support in the development of corporate strategies and business models. Extensive competencies in innovation and technology management assist organizations in their digital transformation.
- **Logistics and Supply Chain Management**
  The design of intelligent logistics and material-flow systems as well as a modern ICT software architecture combine to form the holistic approach of the Group for Production.

Collaboration and future topics

The Fraunhofer Group for Production offers a multitude of services ranging from technology consulting and collaborative research through to the solving of requirements and challenges via collaborative implementation projects. In addition to “quick wins” from potential analyses and innovation workshops, feasibility studies and bespoke system developments and integrations are among the frequently implemented formats for successful cooperation with industry. The Group thereby designs and optimizes technologies, processes and products through to the production of prototypes and small series. In addition, the experts offer advice on the selection of the right solutions and continuously empower people in dealing with new innovations in production and logistics.

The Fraunhofer Group for Production is a strong partner at all centers of German production research and is consequently excellently networked with politics, industry and science in Europe and around the world. Furthermore, the member institutes are involved in various thematically focused project centers which, in turn, consolidate the scientific findings within the range of services offered by the Group.

In view of a rapidly changing future and the associated diverse change and transformation processes that are increasingly influencing our living and working environments, the Fraunhofer Group for Production participates in various publicly and industrially funded and effective research projects. The selected future topics include, for example:

- Resilient value creation systems
- Smart maintenance
- Digital transformation and industry 4.0
- Artificial intelligence in production and logistics
- Biological transformation
- Human-robot collaborations
- Additive manufacturing
- Battery cell production
- Hydrogen technologies

The Fraunhofer Group for Production thereby participates in high-profile events and is represented at numerous trade fairs and events throughout the year (e.g. Hannover Messe, Formnext, Control, Maintenance), in order to make the latest findings and solutions accessible to a wide audience, for example in the form of collective exhibits.

Contact

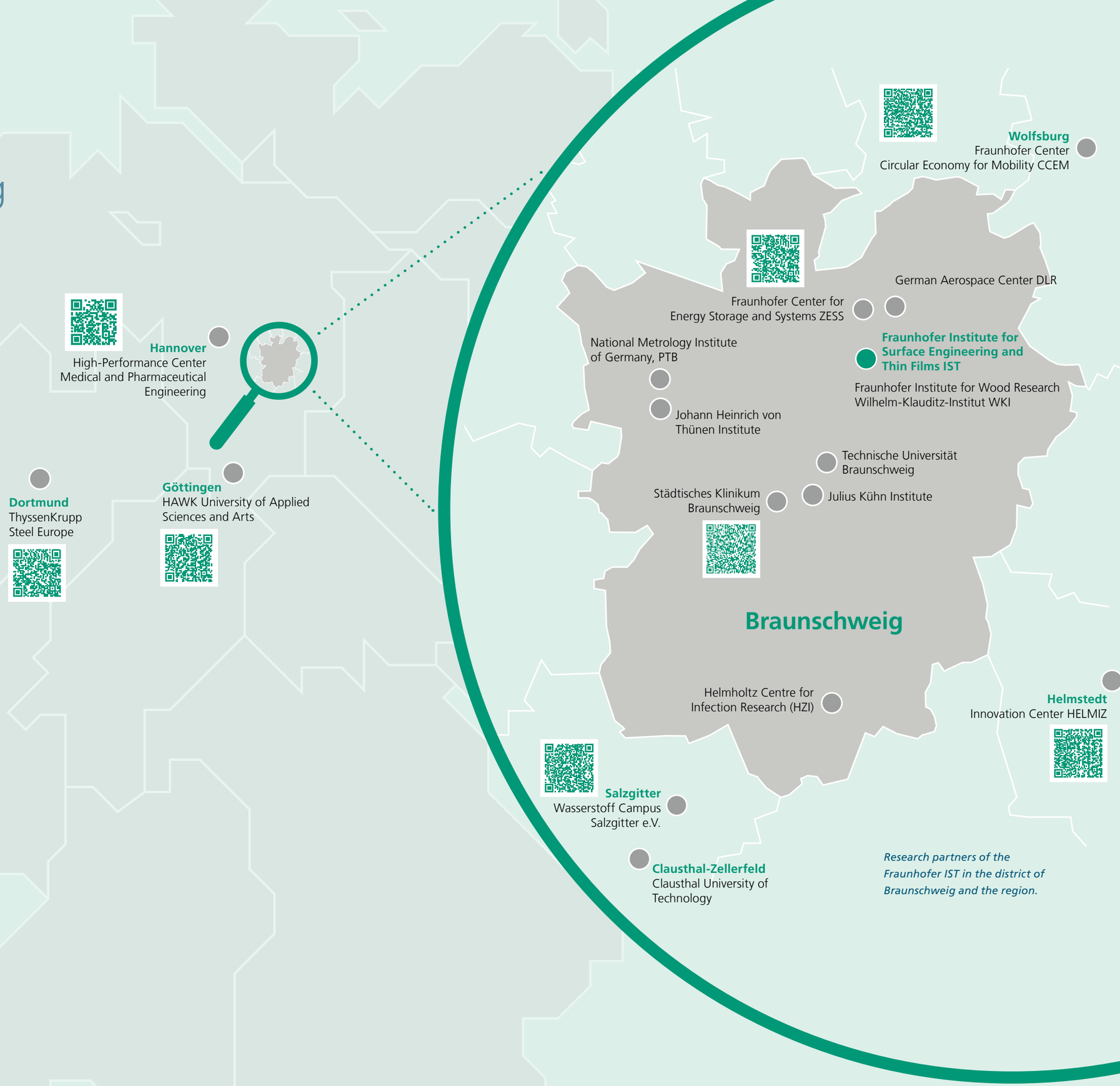
Chairman of the
Fraunhofer Group for Production
Prof. Dr. Welf-Guntram Drossel
Fraunhofer Institute for Machine Tools and Forming Technology IWU
Reichenhainer Straße 88
09126 Chemnitz
welf-guntram.drossel@iwu.fraunhofer.de

Business Office Manager
Niels Schmidtke
Fraunhofer Institute for Factory Operation and Automation IFF
Sandtorstraße 22
39106 Magdeburg
niels.schmidtke@iff.fraunhofer.de

www.produktion.fraunhofer.de

Regional and nationwide networking

31 institutions – 70 locations – 19,600 employees:
In order to network knowledge, sustainably promote innovation and strengthen the leading position of the Braunschweig science region, diverse scientific institutions in South-East Lower Saxony have joined forces to form the ForschungRegion Braunschweig e.V. Included among them are universities, colleges, federal research institutes, Helmholtz institutes, Fraunhofer institutes, Leibniz Association research establishments, museums, libraries and the Klinikum Braunschweig. Cooperation and partnerships already exist between many of these members and the Fraunhofer IST. The institute is also networked throughout Germany, beyond the ForschungRegion Braunschweig. The map shows examples of our network:



Research partners of the Fraunhofer IST in the district of Braunschweig and the region.

The Competence Network Industrial Plasma Surface Technology e. V.

INPLAS

Highlight in 2023: General Meeting at the Wasserstoff Campus Salzgitter e. V. on the premises of Robert BOSCH GmbH.

The INPLAS e. V. competence network pursues the goal of publicizing the potential of plasma technology and supporting, promoting and presenting developments in the numerous fields of application. The network is accredited by the German Federal Ministry for Economic Affairs and Climate Action in the "go-cluster" program and has been awarded the Silver Label for Cluster Management Excellence. INPLAS currently has 53 members from industry and science, with around 200 active individuals. 75 percent of INPLAS members come from industry.

In 2023, INPLAS once again organized a wide range of activities relating to the topics of surface technology:

INPLAS working groups

In May 2023, a meeting of the "Tool Coatings" working group took place in which the Fraunhofer IST presented its expertise and solutions in the field of wear analysis and the development of efficient wear protection.

The working group "Novel Plasma Sources and Processes", headed by Dr. Anke Hellmich, Applied Materials GmbH & Co. KG, Matthias Nestler, scia systems GmbH, and Dr. Ulf Seyfert, Von Ardenne GmbH, dedicated the spring meeting at scia Systems GmbH in Chemnitz to optical lattices by means of ion beam trimming, the coating of optical components with the aid of a digital twin, remote plasma sputtering HiTUS®, and the powerful magnetron for microwave processes. The fall meeting at the Wasserstoff Campus Salzgitter e. V. focused on the application possibilities of plasmas in the field of hydrogen technology and for CO_2 conversion. A tour of Robert Bosch Elektronik GmbH successfully rounded off the event.

Participants at the third meeting of the "Digitalization and AI" focus group in June discussed the status of and development requirements for the application and implementation of "Industry 4.0" in industrial plasma and coating technology. The meeting was chaired by Marija Rosic from the Institute of Machine Tools and Production Technology at the TU Braunschweig, and Hanno Paschke from the Fraunhofer IST. The presentations addressed the potential and application examples of AI in production, the digitalization of electroplating process chains, energy efficiency in thermochemical edge-layer treatments, machine learning in industrial heat treatment, and service treatment through the application of hybrid IoT technologies.

The 24th meeting of the joint committee GA "Combined Surface Technology", which is chaired by Prof. Dr. Petra Uhlmann from the Leibniz Institute of Polymer Research, addressed surface technology for the prevention of icing, new developments concerning the effects of zwitterionic polymer films on the icing of surfaces, and current developments in the "Industrial Collective Research" funding program of the German Federal Ministry for Economic Affairs and Climate Action.

INPLAS collaborative project "Plasma diagnostics for plasma processes 4.0 – PDP 4.0"

The aim of the INPLAS collaborative projects is – within the framework of a joint project with variable creative leeway, manageable outlay and no obligation to publish – to enable an entry into a subject area with various partners. In the project "Plasma diagnostics for plasma processes 4.0 – PDP 4.0", eight INPLAS members worked together in the form of pre-competitive collaborative contract research in order to gain insights into the possibilities and limitations of various methods of process diagnostics in the digitalization of production processes. The project was completed in June 2023 and follow-up projects are already being planned.

13th HIPIMS conference

In June 2023, INPLAS participated in and was a co-organizer of the 13th International Conference on Fundamentals and Industrial Applications of HiPIMS, which was organized by Sheffield Hallam University in collaboration with further partners. The Conference took place in Venlo, the Netherlands, as part of the 40th anniversary of IHI Hauzer Techno Coating B.V., an important player in the field of plant engineering, in particular for HiPIMS applications. The focus lay on developments in the field of the hydrogen economy, in particular the coating of bipolar plates, digitalization in the field of surface technology, the latest developments in the field of tribological coatings for applications in machining and aviation, and active process monitoring and control of industrial HiPIMS processes.

47th meeting of the industry working group "Tool Coatings and Cutting Materials" (IAK)

At this event, which took place in Braunschweig at the beginning of May 2023, tool manufacturers and users, mainly from industry, met to discuss the latest developments and trends in the field of cutting tools and their coatings.

The IAK is jointly organized by the partners the IWF from the TU Berlin, the Fraunhofer IPK, the Fraunhofer IST and INPLAS e.V. and takes place alternately in Berlin and Braunschweig.

18th INPLAS General Meeting

The 18th INPLAS General Meeting took place at the Wasserstoff Campus Salzgitter. The activities in the reporting period were presented, new members were introduced, the Executive Board and the auditors were elected and planned activities were discussed. Through presentations and tours, participants were able to obtain information regarding current projects and possibilities at the Wasserstoff Campus Salzgitter e. V.

On November 23, 2023, INPLAS was successfully recertified with the Silver Label of the European Cluster Excellence Initiative (ECEI). The assessment process was conducted within the framework of the "go-cluster" program and in cooperation with the European Secretariat for Cluster Analysis (ESCA). "With the successful assessment, you have been able to prove that you are contributing towards the continuous further development of your cluster initiative and are one of the most efficient cluster organizations in Germany."

In this context, we would also like to thank our members and partners, without whom this success would not have been possible.

52 INPLAS members

INPLAS member overview (status: 2023).

Find out more about our members:

https://inplas.de/en/

Contact

Dipl.-Ing. Carola Brand
Managing Director
Phone +49 531 2155-574
carola.brand@inplas.de

Dr. Jochen Borris
Project Manager
Phone +49 531 2155-666
jochen.borris@inplas.de

Memberships

Publications

Dissertation

Schulz, Paul Philipp (2023). Model-based examination of dust particle contamination in plasma coating processes. Fraunhofer Verlag. https://doi.org/10.24406/publica-555

Patents granted

Biehl, S.; Paetsch, N.; Meyer-Kornblum, E. (2023): Sensorisches Schichtsystem. DE 10 2018 218 300A1

Vergöhl, M.; Pflug, A.; Bruns, S.; Zickenrott, T. (2023): Device and method for producing layers with improved uniformity in coating systems with horizontally rotating substrate.

Vergöhl, M.; Pflug, A.; Bruns, S.; Zickenrott, T. (2023): Device and method for producing layers with improved uniformity in coating systems with horizontally rotating guiding.

Conference contributions

Baars, J., Clos, D. P., Orangi, S., Dilger, N., Cerdas, F., Zellmer, S., Herrmann, C., Strømman, A. H. (2023): Enhancing Battery Sustainability: A Novel Sustainability Modelling Platform for Battery Production. International Battery Production Conference – IBPC 2023, Braunschweig, 07.-09.11.2023 – Poster.

Bandorf, R. (2023): Industrial Scale Reactive HIPIMS - Applications and Active Process Contro. TACT 2023, 12.-15.11.2023 – Talk.

Bandorf, R. (2023): Materialentwicklung und Messverfahren für die Wasserstoffwirtschaft. TransferTalk "Wasserstofftechnologien entlang der Wertschöpfungskette", 20.06.2023 – Talk.

Bandorf, R. (2023): Reactive HIPIMS of Oxides for Industrial Processes. International Conference on Fundamentals and Industrial Applications of HIPIMS 2023, 12.-15.06.2023 – Talk.

Bandorf, R. (2023): Thin Film Coating Solutions for Hydrogen Economy. 66th Annual SVC Technical Conference, 08.-11.05.2023 – Talk.

Bandorf, R., A. Pflug, S. Bruns, T. Melzig, H. Gerdes, F. Oldenburg, M. Vergöhl, C. Herrmann (2023): Digital Transformation of Vacuum Coating. International Forum on High-Density Plasma Coatings and Process Control, 14.03.2023 – Talk.

Bandorf, R., Ehiasarian, A. (2023): High Power Impulse Magnetron Sputtering HIPIMS. 66th Annual SVC Technical Conference, 08.-11.05.2023 – Talk.

Bandorf, R., Ehiasarian, A. (2023): HIPIMS Applications. International Conference on Fundamentals and Industrial Applications of HIPIMS 2023, 12.-15.06.2023 – Talk.

Bandorf, R., Ehiasarian, A. (2023): Practice and Applications of High Power Impulse Magnetron Sputtering. 66th Annual SVC Technical Conference, 08.-11.05.2023 – Talk.

Bandorf, R., Gerdes, H. (2023): Application of Reactive Sputtering. 66th Annual SVC Technical Conference, 08.-11.05.2023 – Talk.

Bandorf, R., Gerdes, H. (2023): Application of Reactive Sputtering. International Conference on Fundamentals and Industrial Applications of HIPIMS 2023, 12.-15.06.2023 – Talk.

Baron, S. (2023): Thin, smooth and uniform HFCVD-diamond films for antireflective coatings. 11th International Conference on Hot-Wire Chemical Vapor Deposition, 17.-19.04.2023 – Talk.

Barton, D. (2023): DLCplus – Improved DLC coatings by more efficient process design. V2023 – Vakuum & Plasma, 18.-21.09.2023 – Talk.

Barton, D. (2023): Thin film process modelling at different scales – from kinetic simulations to digital twin. Workshop Innovationstreiber Oberflächentechnologie – Von der Simulation zur Beschichtung, 28.-29.11.2023 – Talk.

Bialuch, I., Rimpl, K., Lachmann, K., Finke, J. (2023): Systematic evaluation of the influence of material properties and punch coatings on sticking. 5th International Symposium on Pharmaceutical Engineering Research SPhERe, Braunschweig, 18.-20.10.2023 – Poster.

Britze, C. (2023): Uniformity Control of Optical Precision Coatings on 2D and 3D Components. 66th Annual SVC Technical Conference, 08.-11.05.2023 – Talk

Brokmann, J. (2023): Thin film lithium metal anodes for solid-state batteries manufactured via sputter deposition. International Battery Production Conference IBPC 2023, 07.-09.11.2023 – Talk.

Brückner, T. (2023): Self-Organizing Ti-Si-B-C-N Nanocomposite Multiphase Coatings for Wear Reduction. 10th NRW Nano-Conference, 24.-25.05.2023 – Poster.

Bruns, S. (2023): Extending the Potential of Optical Monitoring Software by Full Machine Control and Quality Assurance. 66th Annual SVC Technical Conference, 08.-11.05.2023 – Talk.

Bruns, S., Henning, P., Melzig, T., Reck, J., Shay, T., Richter, U., Vergöhl, M. (2023): High-speed triggered in situ broadband ellipsometry at turntable PVD coating machines. 12th Workshop on Spectroscopic Ellipsometry (WSE), Prag, 19.-21.09.2023 – Talk.

Cerdas, F. (2023): Life cycle management for e-mobility services. 11th International Conference on Life Cycle Management LCM 2023, 06.-08.09.2023 – Talk.

Clos, D. P., Baars, J., Cerdas F., Zellmer S., Hermann H., Strømman H. M. (2023): Towards a sustainable battery manufacturing modelling platform. 11th International Conference on Industrial Ecology (ISIE-2023), 05.08.2023 – Talk.

Conference contributions

Clos, D. P., Baars, J., Cerdas, F., Zellmer, S., Herrmann, C., Strømman, A. H. (2023): A Battery Platform for Sustainability Assessments in the Battery Production Industry. 11th International Conference of Life Cycle Management – LCM 2023, 06.-08.09.2023 – Poster.

Duckstein, R. (2023): Digitale Werkzeuge für mehr Nachhaltigkeit. 20. Norddeutscher Galvanotag, 11.05.2023 – Talk.

Gerdes, H. (2023): Digital Transformation in Thin Film Deposition. International Conference on Fundamentals and Industrial Applications of HIPIMS 2023, 12.-15.06.2023 – Talk.

Gerdes, H., Schütte, T. (2023): Digitalization in the Coating Industry- Does it (already) improve Production and Product?!. 66th Annual SVC Technical Conference, 08.-11.05.2023 – Talk.

Grube, M. (2023): Development of a scalable production process of sulfide-based solid electrolytes and characterization of product properties. International Battery Production Conference IBPC 2023, 07.-09.11.2023 – Talk.

Henning, P., Bruns, S., Melzig, T., Britze, C., Kreuzer, K., Vergöhl, M. (2023): Neue Aktivitäten zu optischen Beschichtungen. 39. Arbeitskreistreffen des Arbeitskreises DUV/VUV-Optik, Braunschweig, 24.05.2023 – Talk.

Herrmann, C. (2023): The Hydrogen Campus Salzgitter an Innovative Hub for Transformation of the Region. International Conference on Fundamentals and Industrial Applications of HIPIMS 2023, 12.-15.06.2023 – Talk.

Herrmann, C., Daub, R., Sauer, A. (2023): Defossilierung der Produktion - quo vadis?. CO_2-Neutrale Frabrik, 20.-21.6.2023 – Vortrag.

Höfer, M. (2023): Optimization of HWCVD Process Conditions for the Deposition of Silicon Nitride Coatings with Specific Properties. 11th International Conference on Hot-Wire Chemical Vapor Deposition, 17.-19.04.2023 – Talk.

Husmann, J., Baars, J., Bein, T., Herrmann, C., Cerdas, F. (2023): TranSensus LCA. International Battery Production Conference – IBPC 2023, 07.-09.11.2023 – Poster.

Imdahl, Christoph (2023): Fabriktransformation – Digital. Defossilisiert. Wirtschaftlich. TransferTalk »Wasserstofftechnologien entlang der Wertschöpfungskette«, 20.06.2023 – Talk.

Körner, S. (2023): In-Situ Process Control of Reactive HIPIMS Based on Optical Emission Spectroscopy. 66th Annual SVC Technical Conference, 08.-11.05.2023 – Talk.

Körner, S. (2023): Reactive High power impulse Mangetron Sputtering (HIPIMS) of titanium oxide: Transition from metallic to poisoned regimes ananlyzed by optical emission spectroscopy. International Conference on Fundamentals and Industrial Applications of HIPIMS 2023, 12.-15.06.2023 – Talk.

Körner, S., Bandorf, R., Gerdes, H., Sittinger, V., Vergöhl, M., Bräuer, G. (2023): Process Development of Reactive HIPIMS. International Forum on High-Density Plasma Coatings and Process Control, 14.03.2023 – Talk.

Krinke, S. (2023): Carbon-neutral and circular products – opportunities and risks for the chemical industry. Envalior customer sustainability event, 28.09.2023 – Talk.

Krinke, S. (2023): Decarbonization of passenger transport – a strategic Life-Cycle approach. European Automotive Decarbonization and Sustainability Summit, 12.-13.04.2023 – Talk.

Krinke, S. (2023): Dekarbonisierte Produkte – Beitrag von Produktion und nahhaltigen Lieferketten. Innovationstag 2023 Laserzentrum Hannover, 01.11.2023 – Talk.

Krinke, S. (2023): Life-Cycle Engineering und Decarbonization along the value-chain. CIRP Design Conference 2023, 17.-19.05.2023 – Talk.

Lachmann, K. (2023): Spektroskopische Methoden zur Charakterisierung organischer Oberflächen und Beschichtungen. TransferTalk "Oberflächenanalytik in der Qualitätssicherung", 17.10.2023 – Talk.

Lachmann, K., Köhler, R., Neubert, T., Viöl, W., Thomas, M. (2023): Plasmaverfahren im 3D-Druck. Digital Implant Innovation Forum #2, 11.09.23 – Talk.

Lachmann, K., Neubert, T., Scopece, P., Patelli, A., Moroni, L., Thomas, M. (2023): Einsatz von Atmosphärendruck-Plasmaverfahren zur Steigerung der Akzeptanz 3D-gedruckter polymerbasierter Scaffolds. EFDS-Workshop "Wenn die Antwort in der Schicht steckt", 27.-28.02.2023 – Talk.

Lachmann, K., Omelan, M., Kielstein, J.T., Hossain, H., Thomas, M., Sunder, W., (2023): Das Patientenzimmer der Zukunft als Reallabor. 44. Workshop des ak-adp Anwenderkreis Atmosphärendruckverfahren, 27.-29.09.23 – Talk.

Mejauschek, M., Weber M., Demmler M., Heidrich J. (2023): Optimization of high-temperature tool materials by diffusion processes. V2023 – Vakuum & Plasma, 18.-21.09.2023 – Poster.

Menzler, M. (2023): Synthesis of layered oxide cathode active materials from secondary resources. International Battery Production Conference IBPC 2023, 07.-09.11.2023 – Talk.

Neubert, T., Schumann, L., Lachmann, K., Thomas, M., (2023): The Treatment of graphite powder by using an atmospheric pressure plasma jet. 20th Plasma Technology Conference PT20 Bochum, 27-29.03.2023 – Talk.

Ortner, K. (2023): Herstellung von hochreinem Wasserstoff aus biogenen Reststoffen. TransferTalk "Wasserstofftechnologien entlang der Wertschöpfungskette", 20.06.2023 – Talk.

Paschke, H., Brueckner, T., Thewes, A., Peddinghaus, J. (2023): Enhanced tool surface properties against adhesion in aluminum forging. 49th International Conference on Metallurgical Coatings and Thin Films (ICMCTF 2023), 22.-26.05.2023, San Diego, CA – Talk.

Paschke, H., Peddinghaus, J. (2023): Standmengenoptimierte Gesenkoberflächen für die temperierte Aluminiummassiv-umformung (IGF 20780 N). IMU Jahrestagung 2023, 14.-15.06.2023, Dortmund, Zeche Zollern – Talk.

Patzke, K., Weber, S., Baars, J., Dilger, N., Cerdas, F., Zellmer, S., Herrmann, C. (2023): Towards a harmonized approach for prospective environmental and economic assessments of battery innovations. International Battery Production Conference IBPC 2023, 07.-09.11.2023 – Poster.

Pflug, A. (2023): PVD-Deposition on 3D Substrates Tailored by a Digital Twin. 66th Annual SVC Technical Conference, 08.-11.05.2023 – Talk.

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Fraunhofer Institute for Surface Engineering and Thin Films IST

Director of the Institute
Prof. Dr.-Ing. Christoph Herrmann

Deputy Director of the Institute
Prof. Dr.-Ing. Sabrina Zellmer

Riedenkamp 2
38108 Braunschweig, Germany
Phone +49 531 2155-0
Fax +49 531 2155-900

info@ist.fraunhofer.de
www.ist.fraunhofer.de

Editorial and coordination
Dr. Simone Kondruweit
Sandra Yoshizawa
Daniela Kleinschmidt

Layout
nils hildebrandt designer
www.nilshildebrandt-designer.de

Contact

Fraunhofer Institute for Surface
Engineering and Thin Films IST
Riedenkamp 2
38108 Braunschweig, Germany
Phone +49 531 2155-0
Fax +49 531 2155-900
info@ist.fraunhofer.de

www.ist.fraunhofer.de