

ABSTRACT BOOKLET

2025 VACUUM
2025 PLASMA
2025 SURFACE
2025 COATING

V2025

International Conference & Exhibition

INTERNATIONAL CONGRESS CENTER DRESDEN

October 13 – 16, 2025
Dresden, Germany

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V2025 Abstract Booklet

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13 October, 2025

TUTORIAL »Sustainability in Surface Engineering«

Challenges for coating technology: What is sustainability, what are the regulatory requirements and how is the CO₂ equivalent calculated? How to optimize CO₂ emissions by choosing the right surface treatment and coating tool, the right materials and optimal processes. Questions we would like to discuss in this workshop. For your company, sustainability means thinking and acting for the long term. At least two aspects of sustainability must be taken into account in surface technology. Surface technology and surface treatments can significantly reduce the environmental impact of the products and systems that rely on them. On the other hand, the application of surface technologies also has an impact on the environment. It is important to understand the quantitative value on a CO₂ equivalent basis for a system and technology. What can be done to reduce the CO₂ equivalent of surface treatment technologies?

Main Topics

Challenges for coating technology: What is sustainability, what are the regulatory requirements and how is the CO₂ equivalent calculated? How to optimize CO₂ emissions by choosing the right surface treatment and coating tool, the right materials and the right processes. Questions we would like to discuss in this workshop.

Target Group

Design engineers, process engineers and also newcomers to the topic of „sustainability“ from the areas of coating systems and manufacturers of vacuum toolmaking systems and users

External venue at Fraunhofer FEP, Dresden

The event will take place at the *Fraunhofer Institute for Electron Beam and Plasma Technology FEP* in *Winterbergstraße 28, Dresden*.

Tutorial Committee

- **Uwe Heydenreich**, TRUMPF Hüttinger + Co. KG, Freiburg im Breisgau, Germany
- **Prof. Dr. Stephan Krinke**, Fraunhofer Institute for Surface Engineering and Thin Films IST, Technische Universität Braunschweig

TUT01 | Sustainability in coatings: PVD processes from an energy efficiency perspective

Marcus Schüler

mfts modular thin film systems gmbh, Kesselsdorf, Kesselsdorf, Germany

The sustainability of vacuum coating systems is significantly influenced by system design and process optimization. This presentation gives an overview of key factors within a coating system that have an impact on its carbon footprint.

These range from the selection of suitable pump systems and intelligent automation concepts to the recycling-friendly design of components such as shieldings and the adaptation of processes to the actual application as defined by requirements.

The three main processes—magnetron sputtering, thermal evaporation, and electron beam evaporation—are used to illustrate the respective basic principles. In this context, the parameters that have a particular influence on ecological sustainability are highlighted.

The aim of the presentation is to share practical ways to minimize environmental impact – and, as a welcome bonus, also reduce operating costs.

Target Group | Design engineers, process engineers and also newcomers to the topic of „sustainability“ from the areas of coating systems and manufacturers of vacuum toolmaking systems and users

TUT02 | Efficiency in Focus: How Modern Vacuum Pumps Save Energy and Costs

Christian Burger

Pfeiffer Vacuum, Industry, Asstar, Germany

Rising energy costs are creating growing challenges for industrial companies. Vacuum pumps, which are indispensable in numerous production processes, offer considerable potential for improving efficiency. The presentation “*Efficiency in Focus: How Modern Vacuum Pumps Save Energy and Costs*” highlights how innovative drive concepts, flexible operating modes, and the targeted selection of efficient pumping principles can significantly reduce energy consumption.

Target Group | Everybody who is interested in new technologies and energy savings.

TUT03 | Sustainability in R&D: Design of Multifunctional Pilot Plants for Long-term Covering a Wide Range of Challenging Demands

Stefan Saager

Fraunhofer FEP, Coating Metal & Energy Applications, Dresden, Germany

Applied research and development (R&D) generates and validates practical solutions for challenges in industry, economy and society, including their transfer into the market. Therefore, appropriate plant engineering is required to bridge the gap between fundamental research and pilot-scale production. Whereas single-use plant systems which are tailored for a specific research task offer no further practical application beyond the dedicated process and still require significant resources for design, manufacturing, commissioning, ramping up, investment, and eventually disposal after the projects, multifunctional plant systems are built around modular, reconfigurable units that can accommodate various processes and scaling-up steps. Their design and fabrication often demand higher initial investment, longer lead times, and more construction materials, but these costs are amortized quickly over multiple projects. Since much of the infrastructure is already in place — particularly in vacuum coating technology, where pre-installed pumps, piping, controls and coating equipment can be reused — multifunctional plants enable faster startup and deliver cost advantages. This approach reduces waste, lowers cumulative resource consumption, and enhances sustainability, provided the system is maintained and updated appropriately. In an era of rapidly evolving industrial requirements, such flexibility is indispensable.

In 2000, the innovative inline vacuum coating plant for sheets and metal strips called MAXI was set into operation at Fraunhofer FEP in Dresden, Germany, to address global research and development needs. This modular system comprises eight chambers and allows for the sequential execution of different process steps. It offers the flexibility to operate in both sheet-to-sheet and roll-to-roll modes. This results in more efficient, faster, and easier progress during the early stages of development, as well as a smoother process transfer for the upscaling. In celebration of MAXI's 25th anniversary and to highlight the benefits of a versatile R&D plant, we will provide an overview of the diverse research projects realized over the years — ranging from metallurgy and semiconductor applications to cutting-edge solutions for today's energy technologies. Additionally, we will discuss current modernization activities.

Target Group | This tutorial contribution is aimed at researchers and developers, plant engineers, funding agencies and investors, as well as policymakers and business leaders. It delivers practical tips, use cases and strategies designed to foster innovation and drive sustainable growth across the industry.

Covered Topics | By attending this tutorial, participants will understand the roles of applied R&D and plant engineering, highlighting the benefits of multifunctional plant systems in relation to sustainability. The tutorial presents various demanding real-world applications, such as corrosion protection, tribological coatings, PV contact layers, graphene as well as cutting-edge technologies for batteries made possible by a single R&D tool.

TUT04 | Navigating through the jungle of EU sustainability requirements: A regulatory overview on CO₂ reduction

Isabel Ruhnke

Luther Rechtsanwaltsgesellschaft mbH, Berlin, Germany

In the face of a rapidly evolving regulatory landscape, companies operating within the EU are confronted with an increasingly complex jungle of sustainability requirements. The ESG framework is shifting under the influence of a political back and forth. This dynamic environment makes it difficult for businesses trying to determine which rules apply, when and to what extent.

Covered Topics | This presentation offers an overview of key ESG-related regulation, with a particular focus on those governing CO₂ reduction and emissions accounting, including CSRD, EU-ETS and CBAM. Moreover, it will highlight the latest developments and changes in the field, e.g. brought about by the so-called Omnibus package.

TUT05 | Measuring and Managing the CO₂ Footprint: Driving Innovation in Surface Technologies

Moritz Günther, Stephan Krinke
Fraunhofer IST, Braunschweig, Germany

The imperative to combat climate change has prompted an increasing focus on the measurement and management of the Product Carbon Footprint (PCF) within various industries, notably also in surface technologies. This presentation aims to provide a comprehensive overview of the PCF, its different scopes and elucidating the critical role of greenhouse gas emissions and their relevance in the context of sustainable surface technologies.

We begin with an introduction to the PCF, defining its significance and implications for environmental accountability followed by key legislative frameworks such as the EU Taxonomy, ISO 14067, and the Corporate Sustainability Reporting Directive (CSRD). These regulations serve as essential benchmarks for industries striving to enhance their carbon management strategies.

Subsequently, we delve into the methodologies employed to calculate the PCF, providing a thorough explanation of Scope 1, 2, and 3 emissions. We will also outline various data collection methods, supplemented by practical examples from industry that illustrate effective PCF measurement and reduction strategies.

Furthermore, the presentation addresses the challenges faced by companies in the surface technology sector when attempting to reduce their PCF. We will explore common barriers and propose viable solutions, drawing lessons from successful initiatives in the industry.

Finally, we will present an outlook on future trends related to PCF and sustainability, along with their implications for the sector. This presentation aims to foster a deeper understanding of the complexities surrounding PCF and to encourage the adoption of sustainable practices that contribute to more environmentally compatible surface technologies.

October 14, 2025

Opening Keynote Lecture

KN-0101 | Next Level Epitaxy - Novel Growth Technique for Compound Semiconductors

Volker Sinhoff, Yilmaz Dikme, Dirk Rost, Ghassan Barbar

ELEMENT 3-5 GmbH, Baesweiler, Germany

With the development of the Next Level Epitaxy (NLE), the ELEMENT 3-5 GmbH has succeeded in creating a manufacturing process for compound semiconductors that enormously reduces the use of resources, drastically reduces costs and also enables better layer homogeneity. Instead of growing at over 1000°C and using toxic gases, NLE grows the layer epitaxially at a process temperature of only 300°C and without toxic gases. In addition to favorable material properties, the low process temperature allows for a completely new architecture of the NLE epitaxy system, which translates into a tenfold increase in capacity and, due to the first-time transition to inline production, a reduction in process time by a factor of 4 to 7. The lecture will provide an insight into the technology and shed light on applications as well as innovative fields.

October 14-15, 2025

WORKSHOP »Surface Engineering for Energy Technologies«

Rapid changes in the Earth's climate and increasingly important geopolitical considerations have led to an urgent need for the introduction of self-sufficient sustainable energy technologies in Europe. Surface and plasma technologies play a key role here, ranging from hydrogen and battery technologies to plasma-based chemical synthesis and photovoltaics. This session will therefore provide an overview of the relevant approaches in these and adjacent areas.

Main Topics

Surface engineering, plasma technologies, energy storage and conversion, battery & hydrogen technologies, photovoltaics, solar thermal applications, plasma based synthesis

Target Group

Technologists, technology scouts of companies, academic researchers, development service providers, surface engineers

Tutorial Committee

- **Dr. Jörg Neidhardt**, Fraunhofer Institute for Electron Beam and Plasma Technology FEP, Dresden, Germany
- *Dave Doerwald*, IHI Hauzer Techno Coating B.V., The Netherlands
- *Adam Obrusnik*, PlasmaSolve s.r.o., Czech Republic
- *Fabian Fertig*, Hanwha Q CELLS GmbH, Thalheim, Germany

Session 1.101 | Plasma coating technologies for Power-to-X applications

Lucia Mendizabal, **Antia Villamayor**, Alonso Alba, Eva Gutierrez
Tekniker, Plasma Coating Technologies, Eibar, Spain

The growing environmental concerns over fossil fuel use and associated CO₂ emissions highlight the need for a transition to renewable energy sources. Solar power is one of the most abundant and accessible renewable sources, but its main challenge is intermittency, thus it has to be stored during high generation periods. An interesting strategy is to convert solar power into value-added molecules like hydrogen or hydrocarbons. This could be tackled using various processes such as electrolysis, photosynthesis, or photo electrochemistry.

All these processes share the common feature of occurring through a chemical reaction, which requires a catalyst to proceed in a fast, selective, and efficient manner. The importance of catalysts in improving energy efficiency is increasing, and the European Union proposes that these catalysts should be able to obtain energy directly from renewable sources, in the form of photons and electrons, to drive the reactions in which they are involved. Among these types of catalysts, two are of particular interest: i) **Photocatalysts**, which can absorb sunlight and either store it in molecular bonds or carry out reactions on their surface and ii) **Electrocatalysts**, which can drive redox reactions when a specific external voltage is applied.

The synthesis of these catalysts is generally carried out using wet chemical methods which are well-studied and offer several advantages. Among these, the ability to achieve a high active surface area is particularly important, as it is essential for obtaining high-performance catalysts. However, these synthetic routes involve multiple steps, are challenging to scale up to an industrial level, and often result in the loss of catalytic material during the process. In addition, the use of multiple reactants leads to the formation of reaction by-products that are largely unusable and harmful to the environment.

Hence, the objective of this presentation is to give an overview about the **feasibility of magnetron sputtering based technologies as an alternative catalyst fabrication technique** to chemical methods, with the aim of reducing catalytic material usage, improving catalytic efficiency, and optimizing the synthesis process.

As an example, **several catalyst layers synthesized by magnetron sputtering acting as electrodes for green hydrogen production** using polymer electrolyte membrane and anion exchange membrane water electrolyzers will be described. Reduction or even replacement of

PGM (Platinum group metals) in these technologies is explored by the utilization of magnetron sputtering. The performance of novel electrodes is compared against conventional ones under single cell in situ testing real operation conditions.

Additionally, the versatility of **magnetron sputtering** in the synthesis and optimization of **photoanodes**, targeting their application in **photoelectrocatalytic (PEC) cells** for the selective reduction of CO₂ to methane will be presented. The performance of these materials will be evaluated under conditions analogous to those on **Mars**, positioning the technology as a potential strategy for **in-situ resource utilization (ISRU)**. This would enable the local transformation of available resources—such as atmospheric CO₂ and wastewater—into **usable fuel (CH₄)** for life support, propulsion, or energy generation in future space missions.

Target Group | Process engineers, Newcomers to the topic of catalyst synthesis by magnetron sputtering techniques for Power-to-X applications (hydrogen generation, e-fuels...)

Covered Topics | Challenges for catalyst synthesis, Magnetron sputtering as an alternative to wet chemical techniques, Green hydrogen generation by water electrolysis, Methane generation by photoelectrochemical (PEC) cells

Session 1.102 | Surface Engineering for Membranes & Barriers

Ralf Bandorf, Kai Ortner, Hans-Ulrich Kricheldorf, Stefan Körner, Rowena Duckstein
Fraunhofer IST, Braunschweig, Germany

Thin film technology plays a crucial role in the hydrogen economy by enabling key performance in hydrogen production, storage, distribution, and utilization. In this contribution we will focus on the use of thin films to either promote or block the movement of selected species. We will focus on three examples:

1. Materials for barriers against hydrogen diffusion and embrittlement.
2. Materials for membranes promoting the movement of oxygen through the solid electrolyte in SOFCs.
3. Materials for membranes for extraction of pure hydrogen from mixed gases.

Target Group | Scientists (Plasma Engineering, Surface Science, Material Science, Energy, ...), Process Engineers, Companies along the hydrogen value chain (hydrogen generation, storage, gas separation, ...)

Covered Topics | Materials selection, Thin film deposition, Application examples

Session 1.103 | PVD coatings for PEM fuel cells and their applicability to Electrolyzer applications

Philipp Schult, **Leonard Rößner**
EKPO Fuelcell Technologies GmbH, Dettingen, Germany

We at EKPO have a long history with metallic bipolar plates for PEM fuel cells. In the presentation I will go into detail with experience in PVD coating for metallic bipolar plates for PEM fuel cells. The application of PVD coating in PEM fuel cells and their profits for operation and industrialization of said PEM fuel cells. After that I will present information for the application and carryover for PVD coatings of bipolar plates for PEM fuel cells to PEM electrolyzer components.

Target Group | Energysupplier, Systemintegrators, R&D coating and components for PEM fuel cell modules, R&D stack PEM electrolyzer.

Covered Topics | PVD coating, Bipolarplates for PEM fuelcells, Components for PEM electrolyzer

Session 1.104 | Unlocking the Potential of HiPIMS for Hydrogen Technologies: A Scalable Approach for Advanced Functional Coatings

Ivan Fernandez

NANO4ENERGY SL, R&D, Madrid, Spain

The global transition toward a low-carbon energy system has placed hydrogen at the forefront of emerging technologies. Devices such as Proton Exchange Membrane (PEM) and Anion Exchange Membrane (AEM) electrolyzers, Alkaline Water Electrolyzers (AWE), and Solid Oxide Electrolysis/Fuel Cells (SOEC/SOFC) are key enablers for clean hydrogen production and utilization. However, their widespread adoption is still limited by materials challenges, particularly regarding the durability and efficiency of metallic components exposed to harsh electrochemical and thermal environments.

Surface degradation, corrosion, and increased interfacial contact resistance remain persistent issues in these systems, especially at elevated temperatures and under strongly acidic or alkaline conditions. In this context, High-Power Impulse Magnetron Sputtering (HiPIMS) emerges as a powerful thin film deposition technique offering significant advantages over conventional Physical Vapor Deposition (PVD) methods. By generating highly ionized plasmas and enabling precise control of energy input, HiPIMS allows the synthesis of dense, defect-free, and highly adherent coatings with tunable chemical and structural properties.

The potential of HiPIMS spans across all major hydrogen technologies. In PEM and AEM systems, corrosion-resistant and conductive coatings can extend the lifetime of bipolar plates. In alkaline systems, diffusion barriers and catalytic coatings improve performance and stability under basic conditions. In SOEC and SOFC applications, thermally stable and oxidation-resistant films are essential to protect interconnects and support materials at high temperatures. Coatings such as amorphous carbon, low-loading platinum group metals, Ni-based and Co-based materials can be engineered using HiPIMS to meet these specific demands.

Equally important is the transition of HiPIMS from laboratory-scale innovation to industrial-scale manufacturing. Historically perceived as a low-throughput technique, recent advancements have significantly enhanced its scalability, making it increasingly compatible with roll-to-roll processing, large-area coating, and high-volume production environments. This upscaling is crucial to meet the growing demand for durable components in the hydrogen economy.

HiPIMS combines materials performance with industrial feasibility, offering a versatile platform for designing next-generation coatings tailored to the diverse requirements of hydrogen technologies. As the hydrogen sector continues to expand, HiPIMS stands out not only as a tool for improving component reliability, but also as a scalable and strategic technology ready to support the global deployment of green hydrogen solutions.

Target Group | PVD coatings, hydrogen economy

Covered Topics | PVD coatings, hydrogen economy

Session 1.105 | Investigation of the Relationship Between Process Parameters, Ion Energy and Thin Film Properties for Coatings in Energy Applications

Teja Roch¹, Nils Fredebeul-Beverungen¹, Maximilian Steinhorst¹, Maurizio Giorgio¹, Volker Weihnacht²

¹ Fraunhofer IWS, Dortmund, Germany; ² Fraunhofer IWS, Dresden, Germany

Thin films, particularly those with nanometer thickness, play a crucial role in electrochemical applications in the hydrogen economy. Examples include fuel cells, electrolyzers, and other catalytic systems. In addition to the selection of suitable materials, processes as well as process parameters are essential for achieving advantageous layer properties. Another challenge is that the desired layer properties must be as homogeneous as possible, even in very thin layers, for example, in the nanometer range. Experiments have shown that, particularly for carbon layers, the layer structure, and thus conductivity and corrosion resistance, can be favorably influenced by adjusting the appropriate bias voltages. Corresponding interfacial contact resistances could be significantly reduced. Furthermore, it was found that for metallic interlayers, the layer structure and thus the formability are particularly determined by the selection of process parameters and methods (arc processes and sputtering). Especially in comparison to sputtering, it is observed that less columnar growth leads to better formability of the layers.

Target Group | Plant manufacturer, Contract coater, Automotive supplier || **Covered Topics** | Arc coating, Fuel Cells, Electrolyzers

Session 1.106 | Developing an Ammonia Value Chain: overview and potential role of coatings in upstream H₂ and NH₃ production technologies

Andrea Monforti Ferrario

IHI Europe Ltd., Advanced Tehcnology Development Department, London, UK

In the global context of need to tackle climate change, decarbonization of energy supply and energy security, several alternative renewable energy vectors are being assessed to be integrated in energy systems worldwide. Although direct electrification via Renewable Energy Sources (RES) seems to be the first go-to solution, this cannot cover all end uses considering constraints in intermittency, variability and instability of power generation from RES (e.g. solar, wind, etc.) together with challenges in energy storage for large energy volumes. In these cases, such as utility-scale baseload power generation and hard-to-abate applications such as industry (cement, steel making, etc.), high-temperature heat generation, etc., chemical energy carriers are more suitable where synthetic fuels such as hydrogen and hydrogen derivatives (such as ammonia, methanol and other chemical carriers) can constitute a suitable alternative drop-in solution to conventional fossil fuels without requiring a substantial modification of energy grid infrastructures respect to switching to direct electrification. For this reason and following the substantial market push, several heavy industry companies are looking into the value chain of renewable hydrogen and derivatives as key products to be included in their portfolio to tackle such transition needs in the energy sector. In particular IHI Corporation is focusing on developing technology to cover the ammonia value chain as a whole, from NH₃ production, to its transport/distribution (via specific infrastructure for NH₃ storage & handling, etc.) up to its conversion in end use applications focusing on power generation (e.g. NH₃ combustion in turbines, boilers and reciprocating engines) as well as on several other industry applications (e.g. use off-grid power generation, maritime applications, etc.). For renewable NH₃ production, renewable H₂ production via electrolysis at suitable technical and cost conditions is a key intermediate step as it constitutes the building block for the NH₃ synthesis loop. In the electrolyser field, being the technology based on thin-films and presenting complex conditions of concomitant thermo- and electrochemical processes, coatings and deposition of thin layers play a key role for performance and final hydrogen cost. Coatings applicable to the electrolyser technologies consist in the deposition of thin film layers with functional roles (electrochemical or chemical) within the Membrane Electrode Assembly (MEA), as well the application of protective layers on the interconnectors/bipolar plates (which are responsible for current collection and distribution but are at the same time exposed to corrosive chemical atmospheres) to prevent oxide formation and degradation of electrical conductivity properties. Successful thin film and surface engineering via different coating techniques can provide several direct (performance, stability, production cost, etc.) and indirect benefits (degradation, energy cost, etc.) on the final hydrogen production cost and for this reason represent a promising & emerging market segment for coating providers to develop tailored coating solutions in close collaboration with technology developers and end users. An overview of possible coating technologies under development by IHI in the H₂ production sector at R&D level is presented.

Session 1.107 | Modeling and Simulation of Plasma-Driven SiO₂ Reduction in the Green14 Reactor

Adam Podgorski, **Quentin M. Wargnier**

Green14, Stockholm, Sweden

We present a novel modeling framework for simulating the plasma-assisted reduction of silicon dioxide (SiO₂) to silicon (Si) in the Green14 reactor, leveraging hydrogen plasma technology. This framework couples plasma flow, multicomponent gas dynamics, and phase change phenomena within a unified multiphysics simulation environment. To solve the resulting complex model, we developed custom numerical integration algorithms and employed machine learning techniques for data-driven calibration and validation, using experimental results from Green14 reactor campaigns.

Our approach outperforms traditional multiphysics models by achieving significant computational speed-up while preserving high fidelity across key physical observables. This contribution highlights how physics-informed modeling, enhanced by modern computational methods, can enable fast, scalable, and accurate simulations of plasma-driven surface and volume processes—offering concrete advances for semiconductor processing and next-generation materials manufacturing.

Target Group | Plasma Processing and Surface Engineering. Computational Modeling & Multiphysics Simulation Experts. Materials Scientists and Process Engineers in Semiconductor and Advanced Materials. Applied Machine Learning in Physics-Based Systems

Covered Topics | Plasma-Assisted Materials Processing. Multiphysics Modeling and Simulation. Machine Learning for Model Calibration and Validation. Computational Acceleration Techniques. Application to Semiconductor and Advanced Materials

Session 1.108 | Simulation and Digital Twin Use Cases in Energy Applications: Thin Film Coating, Etching, and Power-to-X

Adam Obrusnik, Kristina Tomankova, Krystof Mrozek, Petr Bilek, Martin Kubecka

PlasmaSolve, Brno, Czech Republic

Thin film and plasma technologies are central to a wide spectrum of energy applications, including battery electrodes, electrolysis systems, photovoltaic cells, and emerging Power-to-X platforms. These domains, while diverse, often face comparable challenges: translating material science findings into scalable industrial processes, improving energy efficiency, reducing reliance on harmful chemicals, and developing novel plasma-assisted devices for energy conversion or abatement.

By deploying simulation and data mining techniques, industrial stakeholders can reduce the volume of experimental work and trial-and-error by 70–90%, thereby accelerating development and enhancing process control. This contribution presents four representative use cases illustrating how simulation and digital twin approaches are being applied across different segments of the energy sector.

1. **Scaling Research Findings into Industrial Equipment:** Promising materials for battery, PV, and electrolysis technologies are often developed under idealized lab-scale plasma conditions. Multi-physics models can be used to translate these conditions into industrial-scale processes by predicting energy fluxes, plasma species distributions, and other critical process traits. This enables a more controlled implementation of research insights into coating equipment and production lines.
2. **Enhancing Energy Efficiency in Plasma Coating:** Power supply waveforms and coater geometries significantly influence process energy demands. In collaboration with power supply developers, simulations have been used to study the effects of waveform shapes and anode configurations on substrate heating and deposition rate. The findings have guided practical design changes that improve deposition rates per unit power and lower substrate thermal load.
3. **Reducing Environmental Impact of Etching Processes:** The replacement of hazardous gases such as halogens and PFAS in etching processes is gaining momentum. In the HaloFreeEtch Horizon Europe initiative, simulation of plasma chemistry and surface reactions has supported the identification of alternative chemistries that achieve effective etching while minimizing environmental and regulatory concerns. These results highlight the potential of modeling in guiding green process development.
4. **Supporting Power-to-X Reactor Development:** Plasma-based gas conversion systems for Power-to-X are typically developed under significant technical uncertainty. In collaboration with developers of plasma-assisted silicon production, a model-based approach was used to explore reactor configurations and process parameters, identifying operating regimes that enhance conversion efficiency and reduce power losses. Simulations were used throughout early-stage design iterations to steer development decisions. Simulations were used throughout early-stage design iterations to steer development decisions.

When applied systematically, a combination of physics-based modeling, chemistry simulation, and supervised machine learning enables the creation of digital twins for energy-related plasma processes. These hybrid models can capture both the mechanistic foundations and performance metrics of industrial systems, offering a consistent framework for design, optimization, and scaling of energy technologies.

Target Group | Technical experts and managerial staff working in companies that manufacture coating equipment or operate thin film production lines. This group typically faces challenges in maintaining reproducible processes, ensuring uniformity and coating quality, and improving efficiency across PVD, PECVD, and other plasma-based technologies. They are responsible for evaluating new methods and tools that can enhance process stability, reduce development cycles, and support industrial-scale implementation of advanced materials.

Covered Topics | Plasma simulation, Digital twins, Process modeling and data mining, Coating equipment design, Coater layout optimization, Waveform optimization and tuning, Thin film coatings, PVD / PECVD Energy efficiency, Process upscaling, Wafer etching, Plasma-based Power-to-X, Industrialization of research findings

Session 1.109 | Journey to scale: Transitioning ultra-thin solid-state batteries from lab-scale to roll-to-roll production

Abdessalem Aribia

BTRY AG, Dübendorf, Switzerland

BTRY AG, a startup from ETH Zurich and Empa, develops flexible solid-state batteries exclusively using PVD methods. Our anode-free thin-film technology produces ultra-thin (0.1 mm) batteries that charge in one minute and are stable up to 150°C.

Scaling sputtering from precise lab conditions to larger roll-to-roll manufacturing presents technical challenges but also offers inherent advantages. Initial roll-to-roll trials confirmed our approach is scalable and practical, with a new focus on ensuring reliable material handling and process quality.

At BTRY, we focus on direct delivery of battery solutions to industries needing specialized form factors and thermal stability, particularly in IoT applications.

In this presentation, we share our experiences, insights, and lessons learned in moving from lab-scale sputtering to pilot-level roll-to-roll production.

Session 1.110 | Graphite doped Lithium based sputtering targets for DC deposition of LIPON for thin film batteries applications

Peter Polcik¹, Marcus Wolff¹, Szilard Kolozsvari¹, Christian Linke²

¹ Plansee Composite Materials GmbH, Lechbruck, Germany; ² Plansee SE, Reutte, Austria

Target materials made from lithium compounds, such as lithium phosphate (Li₃PO₄), are used in PVD systems for the deposition of lithium-ion electrolyte layers. Such layers are used in the production of thin-film batteries, where the deposited lithium-ion electrolyte exhibit very low electrical conductivity and should preferably be electrically insulating as their suitability as electrolyte layers arises from their ionic conductivity. Typically, the deposition of such lithium-ion electrolyte layers is carried out using a reactive RF/HF sputtering process. For example, when sputtering a lithium phosphate target with additions of nitrogen and/or oxygen during the deposition process, nitrogen-containing LiPON layers characterized by high ionic conductivity, are formed.

However, the low electrical conductivity of conventional target materials made from lithium compounds significantly restricts the use of DC and pulsed DC sputtering methods and thus limits the achievable deposition rates of the deposited lithium-ion electrolyte layers, as fully insulating target materials cannot be deposited using DC and pulsed DC sputtering.

In the present work, carbon enriched electrically conductive lithium phosphate targets were tested using DC sputtering for the deposition of lithium-ion electrolyte layers. The carbon in the targets forms a separate component of the microstructure and results in the significantly increased electrical conductivity as well as thermal conductivity of the target material. The carbon content in the structure was chosen to be in the range of 3-7 wt% to achieve the optimal combination of properties for particularly high-power input and deposition rate. Due to the increased electrical and thermal conductivity of the carbon doped target material, compared to pure Li₃PO₄, higher power input is possible during the sputtering process, as the heat generated in the target material can be dissipated more quickly and the temperature in the target material is reduced. Higher deposition rates compared to RF sputtered target materials are achieved.

The lithium-ion electrolyte layers deposited with the carbon-enriched targets should have, in contrast to the target, very low electrical conductivity or preferably be electrically insulating, as the suitability of such a layer as an electrolyte is determined by its ionic conductivity. Therefore, the carbon contained in the target material must essentially not be incorporated into the deposited LiPON layer. The contained carbon is bound by the oxygen present in residual gases in the coating chamber as CO or CO₂ and subsequently pumped out. The carbon content can be further reduced by an optional reactive sputtering step which ensures that the function of the deposited lithium-ion electrolyte layers is not impaired by the carbon originating from the target material.

Session 1.11 | High-throughput, thin-film coating of powders to enhance batteries

Sébastien Moitzheim

Powall, Delft, Netherlands

Powder-based processes underpin everything from battery materials to pharmaceuticals, yet achieving optimal performance hinges on precise, uniform surface modifications at scale. Over the last decade, Powall has pioneered a continuous nanocoating platform that combines the atomic-level control of Atomic Layer Deposition with the speed and economy of Chemical Vapor Deposition, delivering cost-effective, high-throughput coating of diverse powders. In this presentation, our journey in scaling gas-phase coating methods from lab to pilot scale will be discussed—addressing challenges in handling powders of varied size, shape, and porosity without compromising coating quality.

Target Group | Powder suppliers

Covered Topics | ALD, CVD, powders, batteries

Session 1.112 | Upscaling of Thin Film Coating Technologies for Energy Storage Applications: Some Case Studies

Nicolas Rivolta, Philippe Roquiny, Jeroen Schotsaert, John Chambers, Hugues Wiame, Nils Mainusch

AGC Glass Europe, AGC Plasma, Gosselies, Belgium

AGC Glass Europe is a leader in the mass production of coated glass for over 30 years, utilizing advanced vacuum coating technologies, primarily magnetron sputtering, to produce millions of square meters annually. For more than a decade, AGC Plasma has been designing and manufacturing coating equipment for both the AGC Group and external customers. By combining expertise in equipment manufacturing and large-scale production, AGC Plasma provides comprehensive solutions, including pilot and industrial coater lines, coating prototyping (job coating), and support for production scaling and process optimization. Our core competencies encompass a range of deposition and treatment methods, such as magnetron sputtering, plasma-enhanced chemical vapor deposition (PECVD), evaporation, and ion implantation.

Expanding beyond glass applications, AGC Plasma is driving innovation in vacuum coating technologies for energy-related applications, including anodes, solid electrolytes, bi-polar plates, and Power-to-X systems.

This presentation highlights advancements in anode production, focusing on two next-generation materials aimed at enhancing battery energy density: pure silicon and lithium metal-based anodes. For silicon anodes, we utilize our PECVD technology to deposit thick, amorphous silicon layers onto thin copper foils using our Roll-to-Roll pilot line. Several square meters on both side of copper foils has been already produced. For lithium metal anodes, we employ thermal evaporation to deposit 10-20µm thick, smooth lithium coatings with excellent adhesion. Key process specifications, such as uniformity, deposition rate, material utilization, ultra-thin copper rolling, and safety, are addressed for both technologies.

Target Group | University labs/Research Institutes looking to up-scale an emerging process; Research Institutes/Start-up interested by prototyping samples (job coating) or to get a custom pilot line; Large groups that want a new industrial line, Everybody interested

Covered Topics | Vacuum coating; Vacuum deposition methods; Anode production (Silicium and Lithium metal) Equipment manufacturing

Session 1.113 | Roll-to-roll Vacuum Coating Technologies: Silicon-based Next Generation Anodes for Lithium-Ion Batteries

Claus Luber, Stefan Saager, Steffen Straach, Ludwig Decker

Fraunhofer FEP, Dresden, Germany

The demand for high-energy-density lithium-ion batteries (LIBs) is increasing due to the growing need for portable electronic devices and electric vehicles. Silicon has been identified as a promising anode material due to its high theoretical capacity. But silicon anodes suffer from significant volume changes during cycling, leading to rapid capacity fading and reduced cycle life. To address these issues, vacuum coating

technology has been employed to improve the synthesis and performance of silicon anodes. In this presentation, we will present approaches in the development of high-energy-density LIBs using vacuum technology.

To meet the specific requirements of silicon anodes we start with an innovative approach for the current collector in terms of texture, surface structure and weight, including the preparation of a light-weight current collector by metallization polymer films.

For the anodes, various complementary approaches based on vacuum technology are pursued:

- Synthesis of structured silicon thin film anodes by physical vapor deposition (PVD)
- Deposition of lithium-silicon compound layers to prepare a pre-lithiated Si anodes by PVD

From the production point of view, vacuum thin film technologies can offer process alternatives for battery anodes.

This presentation aims to demonstrate the potential of vacuum technology to overcome the challenges of integrating silicon anodes into next-generation LIBs.

Session 1.114 | Pulsed Laser Deposition for Energy (PLD4Energy) - A new infrastructure at DIFFER: Opportunities and Current Research

Anja Bieberle-Hütter¹, Tim Wilschut^{2,1}, Gertjan Koster³, Chris Baeumer³, Martijn Graswinckel¹, Hamid Hajihoseini¹, Hans van Eck¹, Guus Rijnders³, Marco de Baar¹

¹ DIFFER, Eindhoven, Netherlands; ² RATIO, Eindhoven, Netherlands; ³ University Twente, Enschede, Netherlands

PLD4Energy is a new facility at DIFFER for the deposition and in-situ characterization of thin films by Pulsed Laser Deposition (PLD). The facility is dedicated to the deposition of metal and metal oxide thin films and is designed as a user facility. Our drive is the energy transition, however, same thin films can equally be used in other fields, such as health care, (nano-)electronics, optics, and sensor technology.

The facility consists of a linear transfer line that integrates two PLD chambers (1" and up to 4" deposition area), a sputter chamber (up to 4"), as well as multiple in-situ characterization techniques which range from standard tools, such as reflection high-energy electron diffraction (RHEED), x-ray photoelectron spectroscopy (XPS), optical emission spectroscopy (OES), spectroscopic ellipsometry, to new developments based on x-rays and spectroscopical methods. The facility can handle small samples as well as wafers up 4" and allows for materials screening and component development due to in-situ masking possibilities.

In the presentation, I will explain the main characteristics of the facility and our system engineering approach to design such a complex facility. I will focus on the opportunities of PLD4Energy regarding upscaling of deposition area, novel methods for growth, stoichiometry, and property control, as well as materials screening on samples size. In the last part of the presentation, I will present first results from current research with PLD4Energy in the field of water splitting.

Target Group | Technologists, academic researchers, technology scouts of companies, surface and thin film engineers, materials scientists, system engineers

Covered Topics | Technique of Pulsed Laser Deposition; in-situ characterization of thin films during deposition; materials for energy conversion and storage; system engineering approach for the design and construction of large scale infrastructure; photo-electrochemical water splitting

Session 1.201 | Qcells solar cell technology

Fabian Fertig

Hanwha Q CELLS GmbH, Bitterfeld-Wolfen, Germany

The talk will give an overview of current solar cell technology research and development at Qcells, with a focus on perovskite-on-silicon tandems. This includes the achievement of a 28.6% independently confirmed energy conversion efficiency for tandem solar cells on full-area M10 substrates, and the successful pass of the most critical stress tests for solar cell reliability according to IEC standards.

Session 1.202 | Vacuum Deposition Technology for Piloting Perovskite Tandem

Bruno Heimke, Martin Dimer, Jens Baumann, Frank Löffler
Von Ardenne, Dresden, Germany

VON ARDENNE has a long history in vacuum coating process for optical, electrical, wear coating and solar energy applications. The relatively new perovskite technology is now in transition from lab to high volume manufacturing and the equipment needed faces new challenges:

- A coating width of more than 1.000 mm up to 3.000 mm
- A campaign length of at least 10 days
- Industrial scale dynamic deposition rates to achieve high production throughput and for Si based bottom cells
- Conformal deposition on microtextured or textured pyramidal structures.

Thermal Evaporation

Back more than ten years VON ARDENNE accompanied the transformation from point sources in batch systems to linear evaporators in continuously running inline coating systems especially for the OLED and display industry to achieve cost effective and large area depositions. Now, with the Perovskite based approach at the forefront of next generation photovoltaics new source designs and process control is required to ensure successful upscaling. Results for different perovskite materials with pilot production size evaporation sources will be presented.

Smooth Sputtering

An important topic is the design and the manufacturing of the front side electrode of Perovskite solar cells. One part of the front side electrode is a transparent conductive film (TCO) like ITO. A soft TCO deposition process is required in order to protect the layer below the TCO. Facing Target Sputtering is one of the interesting low damage processes that VON ARDENNE is developing - first results will be presented for perovskite application.

Session 1.203 | Technical Issues of Integrating Thin Film Solar into Green Hydrogen Production

Anna Kindvall, Ivan Rimmaudo, Christian Drost, Stefan Boenisch, Christin Zimmermann, Jens Heinrich, Bettina Spaeth, Robert Arndt
CTF Solar GmbH, Dresden, Germany

The creation of green hydrogen allows many strategic industries to thrive, with green hydrogen playing a role in reducing emissions for steel manufacturing, glass manufacturing, concrete production, transportation, grid stabilization, and many other possibilities. Utilizing Photoelectrochemical (PEC) water splitting, sunlight can be used separate hydrogen from oxygen.

Cadmium telluride (CdTe) thin film solar panels were selected due to the availability, large scale realization, chemical stability, and a high voltage per cell. These advantages made CdTe modules preferable in comparison to other photovoltaic technologies.

Initial prototype testing demonstrated over 10% solar-to-hydrogen efficiency (1). However, the long-term test results suggested that metal back electrode was not uniform across the solar panel. The focus of this investigation was to develop a more robust, continuous metal back electrode.

Improvement of the back electrode was done through thin film material selection and sputter process development. This allowed for a continuous layer to be deposited with improved filling of pinholes and void mitigation. Through pulse sputtering, thin film layers were developed with a higher density, improved durability, and robust layer quality. Material testing was conducted in different electrolyte solutions. Longer term module stability tests with different electrolyte solutions including alkaline and acidic, were also considered.

1. <https://www.sunhydrogen.com/news-posts/tech-update-oct24>

Session 1.204 | Solar thermal energy applications - state of the art and current approaches

Matthias Krause¹, Claudia I. Parra-Montero², Lukas Prager¹, Frans Munnik¹, Fred Fietzke³, Ramon Escobar-Galindo²

¹ Helmholtz-Zentrum Dresden-Rossendorf, Institute of Ion Beam Physics and Materials Research, Dresden, Germany; ² Universidad de Sevilla, Departamento de Física Aplicada I, Sevilla, Spain; ³ Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology, Dresden, Germany

Solar thermal technology comprises two main applications: heat and electricity generation. Heat generation is widely used for water boiling as well as for district, residential, or public building heating, and increasingly also to supply heat for industrial processes. Commercial heat collectors include flat plate collectors, evacuated tube collectors and Fresnel lens collectors. The world-wide capacity for solar thermal heat reached approx. 545 GW installed power at the end of 2024. Concentrated solar power (CSP) can produce both heat and electricity. The most advanced power plants like Cerro Dominador in the Atacama desert are equipped with storage capacities for more than 15 hours and able to maintain stable electricity supply for 24 h. In spite of the obvious advantage - electricity delivery on demand - the installed CSP power stagnates at 7 GW installed peak power since 2023. The future development of CSP for electricity generation, industrial heat production, decentralized district heating and thermal building management will depend mainly on two crucial factors: i) the increase of energy conversion efficiency and ii) the reduction of installation and service costs.

In this talk, an overview of the basic facts, the technological state of the art and the current challenges for solar thermal energy applications will be given. A few remarks will be dedicated to recent approaches to improve the performance and stability of flat plate and tube collectors. The main part of the talk will focus on recent materials science efforts devoted to increase the CSP plant efficiency by implementing higher operation temperatures and reducing the levelized costs of electricity. The concept of solar selective coatings (SSCs) will be introduced and some examples from the ongoing research on design, characterization and thermal testing of SSCs will be given with emphasis on their optical efficiency and thermal stability up to temperatures of 800 °C [1, 2, 3].

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[2] R. Escobar-Galindo et al., Exceptional high-temperature in-air stable solar absorber coatings based on aluminium titanium oxynitride nanocomposites, *Solar Energy Materials and Solar Cells* 271, 112865 (2024)

[3] C.I. Parra-Montero et al., Enhancement of high-temperature stability of solar absorber coatings on metallic substrates through diffusion barriers, *Surf. Coat. Technol.* 507, 132120 (2025)

Target Group | Scientists, engineers, students and company representatives from the field of renewable energies and PVD coatings.

Covered Topics | Solar thermal technology, solar-selective coatings, PVD, in situ processing and analysis, optical film properties.

October 14, 2025

WORKSHOP »Surface Engineering for Tools & Components«

Surface coatings often determine the utility value of tools and components. Hard coatings on tools improve the speed and quality of mechanical machining. Super-lubricating coatings reduce friction losses of sliding components, making them economical and environmentally friendly. Innovative surface solutions can replace critical materials. The workshop with expert speakers from research and industry offers a look behind current solutions in surface technology.

Main Topics

Coating solutions for tools and components, technological insights, surface analytics, materials

Target Group

Technologists, designers, developers and users from mechanical engineering-, automotive- and aerospace industries as well as tool makers and coating providers

Tutorial Committee

- **Dr. Otmar Zimmer**, Fraunhofer Institute for Material and Beam Technology IWS, Dresden, Germany
- **Philipp Immich**, IHI Hauzer Techno Coating B. V., Venlo, The Netherlands
- **Klaus Böbel**, Oerlikon Surface Solutions AG, Balzers, Liechtenstein
- **Dr. Christian Kalscheuer**, IOT at RWTH Aachen University, Aachen, Germany

Session 201 | 35 years AEGD: use of arc electrons for ion cleaning and plasma processing in PVD systems

Jörg Vetter

J.Vetter-S3-consulting, Headquarter, Bergisch Gladbach, Germany

The cathodic vacuum arc, as used in vacuum deposition equipment, generates a highly ionized metal vapour. In current industrial practice, this is used for heating and ion etching the substrate, as well as for the actual deposition process. Electrons generated at the same time as the metal ions can be used to modify and extend the process technology. The electrons can be used for gas plasma generation [1], for electron impact heating [2], for cathodic and anodic diffusion treatment [3,4], for plasma modification during film deposition[5,6] and even for plasma-assisted anodic evaporation [7].

Gas plasma generation is used for industrial ion cleaning, known as arc-enhanced glow discharge (AEGD) [8], as well as diffusion treatment (nitriding) [9,10] in a variety of PVD systems (arc, magnetron sputtering, HiPIMS, DLC, and hybrid systems). This paper discusses the basic plasma technological principles of AEGD set ups realized in various coating systems from batch to inline coaters and highlights latest developments [11].

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Session 202 | Investigation of Coating Wear Mechanisms in Gear Machining Through Combined Experimental and Simulation Approaches

Sascha Beblein, Raphael Lienau, Ronny Fischer, Mithlesh Tote, Christian Gorski
LMT Tools, Schwarzenbek, Germany

A comprehensive understanding of tool wear mechanisms is essential for optimizing the design and performance of coated tools in gear manufacturing. This study combines experimental investigations with various simulation approaches to systematically analyze wear behavior using the well-established fly cutter test - an analogy test for gear hobbing. By linking empirical data with simulation-based insights, a deeper understanding is developed of the causal relationships between local process conditions, the resulting load spectrum, and coating wear. This integrative approach enhances predictive accuracy, reduces reliance on iterative trial-and-error methods, and supports data-driven, performance-optimized tool design for high-efficiency gear machining.

Target Group | Technologists, academic researchers, development service providers, surface engineers

Covered Topics | Surface engineering

Session 203 | From Challenges to Solutions: Rethinking the Limits of Ceramic Processing

Fabian Schneider
ZECHA Hartmetall-Werkzeugfabrikation GmbH, 75203 Königsbach-Stein, Germany

Ceramic materials are often seen as unmachinable due to their brittleness and complexity. Yet with advanced tooling solutions, even these challenges can be transformed into controlled, reliable processes. This talk explores how modern tool technologies are expanding the boundaries of ceramic processing—enabling new applications, improved surface qualities, and more efficient workflows. It's time to rethink what's possible.

Target Group | Engineers, materials specialists, and manufacturing professionals involved in the design, processing, or application of ceramic components. Especially relevant for those seeking improved strategies for the machining of hard and brittle materials—particularly when high surface quality and dimensional accuracy are essential for further processing, such as functional coating or integration into high-performance systems.

Covered Topics | Advanced Ceramic Processing; Micro-Machining of Hard and Brittle Materials; High-Precision Material Removal; Machining Strategies for Functional Materials; Process Optimization for Technical Ceramics

Session 204 | Advanced High Pulse Deposition Technologies – Making the Difference in Tool Performance

Philipp Immich, Julia Janowitz, Daniel Barnholt, Louis Tegelaers, Milena Pazzi
IHI Hauzer Techno Coating B.V., Venlo, Netherlands

The Physical Vapor Deposition (PVD) market is rapidly expanding into new application areas, including components and decorative applications. Among the various PVD technologies, pulse-assisted techniques—such as - High Power Impulse Magnetron Sputtering (HIPIMS)- and Pulsed Arc—are demonstrating clear advantages over conventional methods.

Since PVD became a standard in the cutting tool industry and in high-performance component applications, the drive for improved coating properties—such as lower surface roughness, enhanced thermal stability, and faster deposition rates—has remained a key focus.

At Hauzer, we have made significant progress in recent years by developing these pulsed technologies towards industrialisation. Our advancements not only support coating developers in exploring new material systems but also empower end-users to adopt coatings with enhanced properties for demanding applications.

Our core mission is to develop and industrialize cutting-edge deposition technologies that meet the evolving needs of our customers. In this context, we present the latest innovations in high-pulse deposition, including HIPIMS and Pulsed Arc. These technologies enable the further refinement of established material systems, delivering superior performance in cutting, forming, and tribological applications.

We have successfully applied high-pulse coatings—such as nitride based coatings like AlCrXN, AlTiXN, and hydrogen-free DLC (e.g., ta-C)—on industrial-scale platforms for tribological and tooling applications. The unique properties achieved through these advanced methods have been validated in real-world automotive and tooling environments. Our results confirm that HIPIMS and Pulsed Arc are fully ready for industrial-scale production.

Moreover, these technologies are highly scalable across different machine sizes, offering reliable, cost-effective processes with an excellent balance between coating cost and performance.

In cost-sensitive markets such as decorative, tooling, and tribology, coating volume and scalability are critical. To meet these demands, we have successfully scaled our HIPIMS and Pulsed Arc technologies for use on larger industrial platforms—ensuring high throughput, consistent quality, and alignment with market needs.

Session 205 | Scaleable a-C:H Coating: A Functional Strategy for Rolling Bearing Element Optimization

Joerg Pantfoerder, Thomas Kinkeldei
iwis mobility systems GmbH & Co. KG, Strategy & Business Development. • EMUC/BD, München, Germany

This work explores the potential for reducing friction and wear in mechanical bearings through modern surface coatings. The goal is to develop alternative lubrication strategies that ensure reliable functionality, especially in hygienically sensitive or lubricant-restricted environments. Thin, high-strength coatings are applied to load-bearing components like rolling elements in ball bearings to increase mechanical performance and minimize friction-related energy losses.

Advanced carbon-based coating technologies, such as PVD and PACVD, form the basis for these dry lubricating coatings. Their benefits for bearing components are well documented. However, PVD coating of rolling elements is not yet used in mass production. This is mainly due to limitations in coating plant capacity, especially for seamless coating of spherical rolling elements, and sufficient existing capacity for coating raceways.

Notably, Iwis has demonstrated the INLINE PVD process TRITAN for high-volume production — coating up to 320 million chain pins per year — achieving both technical and economic scalability. This technology enables seamless, cost-efficient PVD coating of not only chain pins but also rolling elements in needle, roller, and ball bearings. Since these coatings must reduce friction under dry or low-lubrication conditions, system-specific adaptation of the coating process is essential.

Laboratory tests under both lubricated and dry-running conditions assess coated components' tribological behavior. A central aspect of these investigations is the transferability of findings from the processing of a-C:H coatings using conventional batch systems to the application and

optimization of INLINE coating technologies. Special attention is given to how coating surfaces respond to contact, mixed, and frictional forces. The test results show that, even with lower degrees of process freedom than batch systems in the INLINE process, coatings significantly reduce frictional torque and extend the service life of bearings.

These results highlight the potential of dry lubrication solutions in areas with marginal lubrication conditions (low kappa values), where conventional lubricants alone are not sufficient for all operating conditions. Reducing friction losses and enhancing wear resistance boosts energy efficiency, extends maintenance intervals, and improves system reliability. The results offer a solid foundation for further process optimization and industrial implementation in demanding applications.

In summary, the combination of modern surface coatings and tailored process control — with specific focus on adapting and scaling INLINE technologies — presents a promising path for enhancing tribological systems. The insights gained open opportunities for future research focused on refining coating technologies to meet the high-performance demands of various industries.

Target Group

Potential for rolling bearing applications:

1. Heavy industry and plant engineering | Rolling bearings in forging presses, punches, jaw crushers and cement, clinker and coal mills often operate under marginal lubrication conditions (low kappa values). Coating can also significantly extend the service life of classifier bearings, tube ball mills, hoists and crane systems.
2. Pump and refrigeration technology | Piston pumps, compressors and refrigeration machines often come into contact with media (e.g. refrigerants), which makes lubrication more difficult. An a-C:H coating reliably protects the bearings against wear and friction.
3. Rolling mills and steel processing | In heavy plate rolling mills, beam mills and medium and fine iron mills, bearings are exposed to extreme loads and high temperatures. Wire guide rollers also benefit from the use of wear-resistant coatings.
4. Turbo technology and high-speed applications | Turbo compressors, turbopumps and turbochargers - for example in the automotive sector - are characterised by very high speeds and significant speed changes. Here, the coating is a cost-efficient alternative to hybrid bearings.
5. Electrical engineering, robotics and power generation | In electric motors, industrial robots and generators (e.g. in wind turbines), dynamic load changes frequently affect the bearings. The coating increases operational reliability and minimises wear, even under changing loads

Session 206 | Industrial production of carbon coatings for complex geometries using highly ionized Plasmas

Konrad Fadenberger¹, Emanuel Tack², Vipul R. Sonawane², Julien Keraudy², Sebastien Guimond², Martin Drabik²

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Diamond-Like Carbon coatings have already a history of more than 30 years in engineering. It started out with simple flat geometries like pump vanes that successfully enabled compact high-pressure pumps. With time the applications became broader and more complex. For example, components needed to work in different chemical environments or different temperature regimes. This led to new coating variants tailored to these environments.

In order to achieve special properties of carbon-based coatings not only the adaption of the process was needed. Also doping elements were added and different synthesis techniques employed. This opened possibilities for a wide range of applications and helped this type of coatings to become a design feature in many different industries to ensure function and reliability for vastly different components and tools.

At Oerlikon we employ a portfolio of techniques to synthesize DLC and ta-C coatings tailored to specific applications. Among those technologies are cathodic arc, sputtering with different setups and PACVD which each have their special advantages. It will be shown how these technologies can be best employed for specific applications. A special focus will be put on complex part geometries and the resulting challenges. Especially sputtering technologies with high ionization degree can be greatly beneficial in overcoming those challenges. Industrialized HPPMS like solutions are able to achieve optimized results on such challenging geometries. On the example of gears it will be shown that performance is achieved that was not attainable using other material and technology combinations.

Target Group | Scientist and engineers working with carbon based coatings, wear resistant coatings and source technologies.

Covered Topics | Carbon based coatings, DLC, ta-C, wear protective coatings

Session 207 | Barrier Coatings: Advanced Deposition Methods and Analytical Techniques

Steffen Wetzel, Anne Zirbel, Jens Emmerlich, Dominik Tiedemann

Robert Bosch Manufacturing Solutions GmbH, BMG-1DE/PAS11, Stuttgart, Germany

With the growing significance of hydrogen as a future energy carrier, new technical challenges arise due to its unique properties. As the smallest and lightest element, hydrogen requires only a very low activation energy for diffusion in solids even at low temperatures, leading to permeation and hydrogen embrittlement of metals. A potential solution to these issues is the application of barrier coatings that can protect technical components from these effects. This presentation will introduce tungsten carbide as a promising barrier coating. To evaluate such hydrogen barrier layers, our own, newly developed and commercially available gas-driven hydrogen permeation test setup was used and details of the device will be presented. To achieve optimal barrier effectiveness, it is crucial to produce highly dense and defect-free layers. Microwave-assisted magnetron sputtering presents a promising new method for depositing dense and smooth coatings. The improved microstructure needed for barrier coatings also comes with a significant increase in hardness compared to coatings applied by regular magnetron sputtering, which makes them also of interest for traditional applications in tool coating.

Target Group | Automotive industry (Focus on fuel cell and hydrogen combustion); Manufacturers of Equipment for Hydrogen Production, Storage, and Transport; Machine Tool Manufacturers; Coating Service Providers

Covered Topics | Microwave assisted magnetron sputtering, Hydrogen permeation measurement, Hydrogen Barrier coatings

Session 208 | Comparison of different corrosion tests to evaluate the corrosion protection properties of Mg-containing PVD-coated steel

Martin Fenker¹, Herbert Kappl¹, Kimon Schmidt², Renate Lobnig²

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This study explores the suitability of electrochemical impedance spectroscopy (EIS) for characterizing the corrosion protection performance of physical vapor deposited (PVD) zirconium nitride (ZrN) coatings alloyed with magnesium. The coatings were applied by magnetron sputtering to steel substrates with polished and blasted surfaces and to glass substrates. This leads to statistically inhomogeneously distributed defects for the coated polished substrates, while an extremely high number of defects occur for coatings of the sandblasted substrates, which are however homogeneously distributed.

A central aim of this work was to assess the capability of EIS to reliably describe the corrosion properties of these coating systems, particularly in comparison with conventional evaluation methods—salt spray testing and potentiodynamic polarization measurements. The coatings were produced with systematically varied magnesium contents. Furthermore, the samples were examined using optical and scanning electron microscopy to support the electrochemical analysis.

The results consistently show that increasing magnesium content enhances the corrosion resistance of the coating/steel system. EIS measurements on polished substrates exhibited well-defined and reproducible spectra that could be successfully modeled using equivalent circuit approaches. In contrast, EIS data from blasted substrates proved more difficult to interpret due to surface roughness, and adequate fitting with standard circuit models was not feasible.

The comparative analysis reveals a strong agreement between EIS, salt spray testing, and potentiodynamic polarization in ranking the corrosion performance of the coatings. These findings demonstrate that EIS is a valuable technique for evaluating Mg-containing PVD coatings on smooth substrates and offers meaningful insights when used alongside established corrosion testing methods. However, its applicability to rougher surfaces remains limited without further model development.

Target Group | Materials Scientists, Corrosion Engineers, Surface Coating Specialists, Electrochemists, Researchers in Metallurgy and Materials Characterization

Covered Topics | Corrosion protection and degradation mechanisms, Physical Vapor Deposition (PVD), Electrochemical Impedance Spectroscopy (EIS), salt spray tests, potentiodynamic polarization tests, replacement of hard chromium

Session 209 | Optimization of DLC coating structure for fatigue resistance improvement

Alessandro Berté, Mirea Cerioni, Paolo Colombi

Lafer Spa, R&D Dept, Piacenza, Italy

Diamond-like carbon (DLC) coatings are extensively employed across diverse industrial sectors due to their excellent tribological performance, combining low friction and high wear resistance. However, their long-term mechanical reliability, particularly in terms of fatigue resistance, remains a critical challenge. The endurance of DLC-based films under cyclic loadings, very often in association with high-speed sliding or impacts, depends upon multiple factors, including coating architecture and layer chemical composition, thickness and other physical properties. Assessing fatigue resistance in thin films is inherently complex, with traditional laboratory testing methods offering limited insight. Moreover, the mechanical characteristics of the substrate, especially hardness and surface finish, significantly influence coating dynamic performance. The aim of this work is to investigate interactions playing a role in fatigue behaviour for different DLC-based coating solutions, resulting in a benchmark useful as a starting point for an improved design of high-performance film for mechanical components.

Various substrate materials, commonly used in engineering applications, were selected: 1.3343 tool steel (both hardened and plasma-nitrided), 17-4 PH stainless steel, and Ti6Al4V titanium alloy. A range of DLC-based coatings, both established industrial solutions and novel experimental formulations, were deposited on these materials samples with different coating techniques, including conventional PACVD, microwave-enhanced deposition and UBM sputtering. The deposition parameters were systematically varied to investigate their influence on structural integrity and fatigue performance.

Comprehensive laboratory analyses, supported by extensive nano-impact testing, revealed key insights into the behaviour of each coating-substrate system. The results lead to the identification of an optimized DLC coating architecture, capable of significantly enhancing fatigue resistance through tailored multilayer design and process refinement.

Target Group | This work targets professionals and researchers in the field of surface engineering, material science, and mechanical engineering. It is particularly relevant to those involved in the development, testing, and industrial application of advanced coatings, including specialists in fatigue performance, tribology, and thin film deposition technologies. Industries of interest include tooling, automotive, aerospace, and biomedical components.

Covered Topics | Diamond-Like Carbon Coating; Fatigue resistance of thin films; Substrate-coating interaction; PACVD, microwave enhanced deposition, UBM sputtering; Multilayer coating architecture; Nano-impact testing; Surface engineering; Mechanical reliability under cyclic loading.

Session 210 | Superior HiPIMS Deposited AlCrN-Coatings For A Wide Range Of Cutting Applications

Christian M. Zeuthen¹, Klaus P. Almtoft¹, Oliver Lemmer², Biljana Mesic², Christoph Schiffers², Stephan Bolz²

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Cutting tools coatings are continuously evolving, and with the increasing focus on longevity, performance and cost-effectiveness it is paramount that new solutions will be found. In this presentation we will present advances in HiPIMS AlCrN nanolayered coatings, demonstrating the potential of that cutting-edge technology for the wide range of cutting applications.

The collaborative research between the Danish Technological Institute and CemeCon AG explores how detailed key process parameter control balances quality and performance with deposition costs.

For different process parameters, we analyze their effect on coating quality indicators such as hardness, crystal phase, chemical composition and microstructure. These indicators are linked with cutting performance and thus profitability in machining production.

The presentation will showcase how collaborative efforts between research and industry can result in enhanced coating performance and industrial benefits. It will show how key parameter adjustments can lead to significant enhancements in both performance and profitability while never compromising on quality.

Join us and see where scientific innovation meets practical application.

Target Group | Tool manufacturers, machining sector, surface technology, cutting tools

Covered Topics | Wear protection, cutting tools, PVD, sputtering, HiPIMS, AlCrN, machining

Session 211 | Tribological properties of coated tools in the machining process

Ugur Ates

Hartmetall-Werkzeugfabrik Paul Horn GmbH, R&D, Tübingen, Germany

While broaching in hardened and tempered 42CrMo4, the cutting edge is subjected to high tribological stress. HiPIMS-coated broaching inserts offer significant advantages in wear behavior, friction and tool life. This presentation analyzes typical wear mechanisms and highlights how coating properties influence process stability. The goal is to provide practical insights to optimizing the broaching process using advanced coating technologies.

Target Group | Tool manufacturer, vacuum technology

Covered Topics | Machining technology, precision tools, tribology, HiPIMS

Session 212 | Assessment of 3D target geometries on the material utilization during sputtering

Erich Neubauer¹, Lukas Zauner¹, Georg Strauss², Stefan Schlichtherle², Nikolaus Weinberger³, Nikolai Kraus³, Oliver Klement³, Daniel Schildhammer³

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The efficient use of sputtering targets is a key factor in reducing material costs and enhancing process sustainability in thin film deposition. In this study, we investigated the influence of different 3D target geometries on the material utilization during the sputtering process. A simplified test setup with a target diameter of 76.2 mm was used in order to validate the experimentally observed material consumption against a set of detailed magnetic field and erosion simulations.

A series of plasma simulations was conducted to predict the effect of various three-dimensional shapes and magnetron configurations on the effective target erosion and plasma distribution. Based on these findings, a target with optimized 3D geometry – with respect to the utilized magnetron setup – was fabricated and subsequently tested under typical DC-sputtering conditions. Comparison of the experimental results with simulation data showed a strong correlation between the calculated erosion profiles and actual material wear patterns. Most notably, the optimized 3D design enabled an increase in total raw material utilization of up to 50%, compared to conventional planar targets. In addition, increased deposition rates and comparable spatial coating distributions were recorded for the 3D shaped design. This work demonstrates the potential of geometry-driven optimization in target design and highlights the value of simulation-based approaches for efficiency improvements in physical vapor deposition technologies.

Session 213 | Simulation of Arc Spot Motion and Target Erosion in Vacuum Arc Deposition Processes

Achim Mahrle, Madlen Borkmann, Steffen Schenk, Otmar Zimmer
Fraunhofer IWS Dresden, Dresden, Germany

Vacuum arc deposition (VAD) is a widely used industrial coating technology for superior tools and components. Main application is the deposition of protective metal nitride layers on cutting tools to enhance the tool performance by enabling increased cutting speeds, prolonged tool lifetimes and a potential reduction of lubrication. Up to now, process adjustments and optimizations in terms of charging arrangements, coating coverages and target material utilization are still highly expensive with respect to time and manpower due to a lack of appropriate design tools. Therefore, a support by means of digital tools could be beneficial for cost reductions. A couple of tools for coating simulations are already available on the market, but these were found to be focused on sputtering and/or CVD-processes. To foster the digitalization of the design of VAD processes in a similar way, this work introduces a modular semi-empirical approach. A first module is designated to describe the arc spot behavior of the electrical discharge as the source of the coating plasma. Its spatial and temporal movement on the cathode (target) surface is essential for both the target utilization and coating quality. The model describes the arc spot motion under the influence of external magnetic fields and given processing conditions as a function of experimentally determined material parameters. It allows for a prediction of local material emission rates and target erosion as well as an evaluation of appropriate control strategies. Based on these results, a second module describes the plasma propagation into the coating chamber up to the computation of local film growth rates on complex shaped substrates on fixtures in motion.

The paper presents the actual state of the ongoing model development, shows computational results of arc spot motion and material deposition and also gives an outlook on the intended functionality of the corresponding software tools.

Target Group | Job coater; Tool maker with coating capacities; Coating device supplier; Researcher & Developer

Covered Topics | Arc-PVD processes; Coating simulation; Arc spot behavior and steering; Target consumption and utilization; Coating coverage and thickness distribution

Session 214 | Cutting performance of Al₂O₃ coatings deposited by High Speed PVD

Kirsten Bobzin, Max P. Möbius, **Parisa Aghdam Tönnißen**
IOT der RWTH Aachen, Aachen, Germany

Cemented carbide tools with Al₂O₃ coatings deposited by chemical vapor deposition (CVD) are still among the best-selling products for turning operations. The drawbacks of CVD, such as thermal cracks, tensile stress formation, and tool embrittlement due to eta phase formation during deposition, have led to increased interest in synthesizing Al₂O₃ at $T > 700$ °C by physical vapor deposition (PVD). However, research in this context is limited and primarily focused on fundamental investigations such as phase formation. Therefore, the machining performance of Al₂O₃ coatings deposited by PVD at $T > 700$ °C leaves significant knowledge gaps. Challenges such as process instability due to target poisoning, deposition of reproducible coatings with the desired stoichiometry, and a narrow process window addressed in literature could be a reason for these limited studies. High-speed PVD (HS-PVD), based on the principle of hollow cathode gas flow sputtering, helps to address these issues. This technology enables high deposition temperatures $T > 700$ °C while maintaining process stability in a reactive oxide process. In this study, the cutting performance of Al₂O₃ coatings deposited by HS-PVD at $T > 700$ °C was investigated during the dry fine turning of C45 steel. This steel was chosen as the workpiece due to its industrial relevance, balanced mechanical properties, and suitability for benchmarking tool performance. Additionally, C45 offers a challenging yet manageable cutting environment, making it ideal for evaluating the wear behavior of HS-PVD coated tools. Thereby, this selection can give first insights into the HS-PVD coating's potential for future industrial applications. Al₂O₃ coatings were deposited with and without a TiAlN interlayer to analyze the effect of the interlayer on cutting performance. The cutting speed $v_c = 120$ m/min gave preliminary insights into cutting performance. Subsequently, the cutting speed was increased to $v_c = 200$ m/min, which falls within the typical industrial range for machining C45 steel. Al₂O₃ coatings from this study exhibit high crystallinity, residual compressive stresses, and high adhesion strength to the substrate. Wear analysis under a cutting speed of $v_c = 120$ m/min reveals that coated tools without an interlayer undergo rapid wear progression, failing before a cutting time of $t_c = 3$ min. In contrast, the TiAlN/Al₂O₃-

coated tools achieve a significantly longer tool life of $t_c = 18$ min. Moreover, the maximum flank wear land width VB_{max} remains below the strict failure criterion of $VB_{max} = 100 \mu\text{m}$ up to a cutting time $t_c = 10$ min under a cutting speed of $v_c = 200$ m/min. Compared to significant studies dealing with the cutting performance of Al_2O_3 coatings deposited by conventional PVD at $T < 700$ °C, no studies are available in this context at $T > 700$ °C. This study contributes the first knowledge about tools coated by HS-PVD at such high temperatures and shows their high potential in real cutting applications.

Target Group | Technologists, academic researchers, surface engineers

Covered Topics | Turning operation, wear resistance coating, cemented carbide inserts, PVD, Al_2O_3

October 14, 2025

WORKSHOP »Surface Engineering for Optics & Optical Components«

The aim is to present innovative technologies in the field of optics, optoelectronics and integrated photonics and their industrial applications in order to demonstrate their potential for future business strategies and production processes in the coating industry. Innovations in optoelectronics and integrated photonics are revolutionising coating technology by enabling more precise, efficient and optically active coatings that open up new dimensions of performance in applications such as sensors, energy-efficient surfaces and highly sensitive optical systems.

Main Topics

Coatings for high-performance optics, optoelectronics, integrated photonics, Ion beam sputtering/figuring, Epitaxie, surface preparation, cleaning/purification

Target Group

Scientist, engineers and technicians working in coating technologies or optical system or microelectronic/semiconductor, development and production.

Tutorial Committee

- **Dr. Sven Schröder**, Fraunhofer Institute for Applied Optics and Precision Engineering IOF, Jena, Germany
- **Dr. Mathias Mende**, Edmund Optics GmbH, Mainz, Germany
- **Dr. Wenko Süptitz**, Industrieverband SPECTARIS, Berlin, Germany

Session 301 | Mirror Coatings for High Power Laser Communication Terminals

Thomas Gischkat¹, Ralph Schlegel¹, Stefan Schwinde¹, Christian Mühlig¹, Tobias Herffurth¹, Sven Schröder¹, Nils Bartels², Moritz Vogel², Thomas Klumpp², Nicolas Steenbergen², Patric Seefeldt³, Thomas Renger³, Erik Klein³, Frank Burmeister⁴, Marina Högerle⁵, Christopher Jahn⁵

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Free-space optical (FSO) laser communication systems became a key technology for satellite to ground and intersatellite communication. Compared to radiofrequency-based systems laser communication terminals offer a higher bandwidth and allow direct communication between sender and recipient. State-of-the-art in-orbit communication systems use continuous-wave (cw) laser at 1550 nm with a laser power of up to 5 W. The combination of high data rates and long distances between transmitter and receiver requires lasers with a higher optical output power. Therefore, future optical systems for satellite laser communication to geostationary orbits (GEO) will use high power lasers with up to 100 W.

Based on the experience of TESAT, optical components for laser powers of 5 W show no laser-induced effects due to light absorption-based processes. For example, localized heating can cause thermal lensing, film stress delamination, and cracks. These effects lead to a reduced performance and, in worst case, to a failure of the optical communication terminal (OCT) system. At the 100 W level and above, manufacturers and suppliers of OCT's (e.g. TESAT and SPACEOPTIX) have no experience with high-power laser-induced effects. Therefore, work on high laser power coating evaluation and development for space-based OCTs including laser testing (combined with molecular or particulate contamination) is crucial.

We investigate the absorption at 1550 nm of single-layer optical coatings and mirror coatings by means of laser-induced deflection method (LID). Subsequently, the results are used to estimate the thermal properties of the HR-coating, respectively. In order to investigate the cw laser handling capability of the coatings, laser damage testing at 1550 nm is performed by means of a raster scan with laser power density of 3 kW/cm². As single layers we deposit SiO₂, Si₃N₄, Al₂O₃ and Ta₂O₅ on high quality P4 polished fused silica. High reflecting thin film mirror structures are grown on fused silica and precision manufactured RSA6061 with RMS roughness of 3 nm and 5 nm. For comparison, an all-dielectric mirror (SiO₂, Ta₂O₅) and a metal enhanced mirror (silver based, SiO₂, Si₃N₄) are deposited on RSA6061 substrates. The coating technologies we use are ion assisted electron beam evaporation and magnetron sputtering. The work is performed on behalf of the European Space Agency (Project "AO/1-11188/22/NL/FGL: High power coating development for space-based laser communication terminals").

Session 302 | Dispersive Optics: production and measurement

Volodymyr Pervak¹, **Aliaksei Kobiak**¹, Daniel Hahner³, Alexander Guggenmos¹

¹ UltraFast Innovations, Garching (Munich), Germany; ² Leybold Optics GmbH, Alzenau, Germany; ³ Ludwig-Maximilians-University, Munich, Germany

Ever since invention of aperiodic optical multilayer structures have been driving the advancement of ultrafast laser technology towards ever broader bandwidth and ever shorter pulses. Deposition of dozens of dielectric layers with sub-nanometer accuracy permits manipulation of the spectral phase and amplitude of optical radiation over a full octave and beyond. We make overview on the progress on dispersive optics since their invention in 1994. Many years of development bring to the benefit that the attosecond physicists could study the electron dynamics in atoms and molecules. The non-linear effects in multilayer ultrafast coating shortly before damage threshold are overviewed as well. We describe ways how to use or post-pone these effects to higher fluences.

Session 303 | Realizing Ion Beam Sputtered Fluorescence Bandpass Filters Applying Optical Broadband Monitoring with Automatic Chip Changing

Matthias Falmbigl¹, Jason George¹, Masatoshi Shibata², Kazuki Chiba², Mathias Mende³

¹ Veeco Instruments Inc., Plainview, USA; ² Edmund Optics Japan Ltd., Yuzawa, Japan; ³ Edmund Optics GmbH, Mainz, Germany

Ion beam sputtering (IBS) is the state-of-the-art coating process to produce highest quality dielectric filters. For fluorescence detection in life science or medical applications typically bandpass, dichroic and long pass filters are applied. To realize the thin film designs with more than hundred layers and a total thickness of several tens of microns, a precise layer thickness determination and cutoff is required. Direct optical broadband monitoring is one suitable approach to reach this precision level. Usually two different thin film designs (e.g. cavity and block filter) are coated on each of the substrate sides to achieve a high transmission in the pass band and a high optical density over the blocking range. If the full monitoring wavelength region is covered by the blocking band or when the spectral resolution is limiting the measurement quality, changing the monitoring substrate during the coating process becomes critical. Therefore, Veeco developed a fully automated chip changing system for their Spector IBS platform. Utilizing this system, the thin film design can be divided between 8 monitoring chips to optimize the layer thickness precision. Within a cooperation between Veeco and Edmund Optics the production of fluorescence bandpass filters applying broadband monitoring with automatic chip changing was evaluated. In this contribution the results of three filters designed for different central wavelength are presented. Furthermore, the impact of two monitoring strategies on the layer thickness errors is discussed.

Session 304 | Substrate-free, Miniaturized Thin Film Filters and Hybrid Photonic Integrated Chips

Anna K. Rüßeler^{1,2}

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Photonics is advancing toward more complex, versatile, yet compact and highly integrated optoelectrical systems, e.g., in quantum technology and telecommunications. At the same time, costs and energy efficiency of such systems can determine the success of a certain technology approach, especially in growing mass markets such as LiDAR and in cost-critical areas such as point-of-care diagnostics, and drives current research towards novel concepts. Multilayer thin-film interference coatings have demonstrated their immense potential for precision optics but have not yet been fully utilised in photonic integrated circuits (PICs). Our substrate-free thin-film technology facilitates hybrid integration of spectral filters in PICs by automated assembly systems. With this particularly miniaturized approach, the thickness of the integrated filter is reduced to the functional layer system. The desirable characteristics of high precision coating technology are transferred to the PIC, while the yield per coating run is maximized from reducing the filter area in a laser segmentation process. Due to the filters' reduced thickness compared to coatings on substrates, and thereby reduced beam divergence inside the element, lens-free integration is possible when singlemode waveguides are used. This talk will also cover the topic of fabricating singlemode waveguides on PICs from glass fibers via laser glass deposition. This method does not only benefit from the desirable properties of fused silica but also from the implicit mode-matching to fiber optical infrastructure. In the same process environment, where the singlemode fibers are welded to the PIC, a laser-based on-chip cleaving process creates smooth end facets with an adjustable angle between 0° and 24°, enabling efficient and versatile integration strategies for the miniaturized filters.

Target Group | professionals and researchers from fields related to photonics, academics and industry professionals, and optical coating experts interested in novel photonic integrated circuit concepts (technology readiness level up to 4) with high potential for footprint and cost reduction

Covered Topics | hybrid photonic integration; automated assembly; substrate-free, miniaturized thin-film filters; multilayer interference coatings; sacrificial substrate; laser glass deposition; laser cleaving of fibers

Session 305 | High Power Optical Coatings for the TRUMPF EUV Drive Laser

Fabian Stöger¹, Lars Jensen¹

¹ TRUMPF SE & Co.KG, Ditzingen, Germany; ² TRUMPF SE & Co.KG, Ditzingen, Germany

Introducing EUV Lithography to the semiconductor market has been the one major technological step to enable newest microchips with highest efficiency and computing power as there are used today and needed in the coming years. TRUMPF supplies the primary laser source to drive plasma emission in the high power extreme ultraviolet source at 13.5nm. Only with this short wavelength the lithographic exposure is possible to write few nanometer sized structures as done in the modern high volume wafer steppers.

As the TRUMPF laser drives the EUV source with almost 40kW of pulsed laser radiation, the optics need to be coated to meet highest precision and purity standards. Low losses, high laser-induced damage threshold as well as tightly controlled phase characteristics and an excellent thermal management are required to deliver the laser power to the target in the EUV source. This presentation gives an overview on what the challenges for these optics are and how to address them.

Session 306 | Quantized nanolaminates pushing the borders of optical interference coatings

Silvia Schwyn Thöny¹, Stephan Waldner¹, Manuel Bärtschi², Clau Maissen¹

¹ Evatec, Trübbach, Switzerland; ² Rhysearch, Buchs, Switzerland

The field of quantized nanolaminates (QNL) is fairly young. In our contribution we will thus first introduce the basic concept of this new class of materials consisting of a stack of nanometer thin layers of a high and a low index material. We will show how a QNL can be manufactured by magnetron sputtering in a deposition system with turntable configuration, which is ideally suited for this purpose. Furthermore, we will show the benefits of the QNL in a range of applications. Thanks to the shift of the absorption edge towards shorter wavelength QNL can be used in cases where the material with the high refractive index material of the QNL cannot be used as a bulk layer due to high absorption. For the material combination SiO₂-Ta₂O₅ the applications are in the UV, whereas for aSi-SiO₂ they are in the NIR to the visible part of the spectrum. The use of QNL also proved to be beneficial in high laser damage threshold applications. Laser damage resistance is linked to the band gap of a material being higher the higher the gap energy. In the case of QNL the absorption edge is shifted towards shorter wavelength as compared to the high index material in the QNL, which is equivalent to a higher gap energy and thus is expected to have higher LIDT. As a third application we will show that the error sensitivity in antireflection coatings can be reduced when using nanolaminates with intermediate refractive index, this compared to the standard designs using high and low refractive index. These examples show that a broad range of applications can benefit from the unique properties of quantized nanolaminate materials.

Session 307 | Coating material supply chains threatened by geopolitical risks - solutions from a European materials manufacturer

Markus Stolze

Umicore Metal Deposition Solutions, Umicore Thin Film Products AG, Balzers, Liechtenstein

The optical coating industry is key enabler for high-technology and premium-photonics applications. Nevertheless, required raw materials originate from a number of other market segments with a geographical footprint much different from that of the coating industry. Also, they are subject to shortage due to local economical or geopolitical factors. Umicore, a manufacturer and materials solutions provider for PVD & EP coating materials, is providing insight into supply chain approaches to reduce impacts of material shortage risks for critical & strategic coating materials.

Target Group | Optical coating companies; Photonics components & systems manufacturers

Session 308 | Advances in large scale ion beam sputtered coatings for various applications: from smartphones to laser fusion

Melanie Gauch

LASEROPTIK GmbH, 30826, Germany

Size does matter. In this talk we present various approaches how to produce high quality coatings with ion beam sputtering on large optics. There are more differences between large and small optics than size only. Main challenges like achieving a good coating uniformity over large areas are depicted. For various industrial applications different kinds of optics are needed and some examples of coatings on large optics are shown.

Target Group | Laser developers, technicians and scientists

Covered Topics | Ion beam sputtering, differences between coating of small and large optics, coating uniformity of large optics

Session 309 | Dedicated methods for nanomechanical characterization of thin films on glass: selected applications

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Optical components very often rely on thin films deposited on glass. The function of the films is primarily optical but in many cases the films are subject to mechanical contact and abrasion or other types of damage. In such cases their wear resistance and hardness as well as adhesion are crucial and have to be determined during the development of the films. Since the optical films are very thin, the most suitable methods for characterization of their mechanical properties are nanoscratch and nanoindentation. In our presentation we will show the use of these methods in various optical applications, ranging from anti-reflective layer through protective layers for photovoltaic cells to electrically conductive layers. Various aspects of the application of the methods will be discussed in order to provide guidelines for reliable measurement of optical films.

Target Group | Development and production of optical coatings

Covered Topics | Nanomechanics, optical coatings, hardness, adhesion

Session 310 | Simultaneous coating of double-side interference filters controlled by optical monitoring

Stefan Bruns¹, Philipp Farr¹, Bernd Galonska², Kristin Galonska², Thomas Melzig¹, Michael Schneider², Waldemar Schönberger², Michael Vergöhl¹

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Optical interference coatings are essential for enhancing the performance of substrates in various optical applications. Traditionally, these coatings are applied in a two-step process—first on one side, followed by flipping the substrate to coat the other side. In this paper, we present an innovative approach that enables broadband monitoring of layer thickness during the simultaneous deposition of coatings on both sides of a substrate, utilizing a specialized sputtering machine. Our algorithm calculates the optical response of a substrate with coatings on both sides. The method leverages the LTR (Left reflectance - transmittance - right reflectance) technique described by Mazilu et al. [1], treating each layer as independent and separated by an infinitesimal vacuum gap. This facilitates real-time calculations of transmittance and reflectance across complex multilayer structures. We implemented a Levenberg-Marquardt algorithm to fit the transmittance spectrum obtained after each rotation of the turntable in the coating machine, allowing for precise real-time thickness monitoring.

Our experimental setup utilized the EOSS®/OPTA X precision optical coating platform [2,3,4], equipped with dual rotary cylindrical magnetrons, plasma sources, and an advanced optical monitoring system. The sputtering targets were configured for both sputter-up and sputter-down modes, enhancing flexibility. Notably, we conducted experiments with two glass substrates positioned 1 mm apart, enabling simultaneous coating on the top side of one substrate and the bottom side of the other.

Results show that our broadband transmittance monitoring effectively captures real-time thickness data during the coating process. The calculated thicknesses from in situ transmittance measurements were compared with ex situ ellipsometry, revealing minor deviations likely due to differences in measurement conditions.

In conclusion, our approach facilitates efficient real-time monitoring for dual-side coatings, utilizing a modified LTR method that accurately calculates the optical response of multilayer coatings. The promising preliminary results indicate potential for further optimization of layer start offset times [5] and automation within the MOCCA+® system [6] for enhanced production efficiency. This method marks a significant advancement for optical coatings with sophisticated specification of substrate flatness, e.g. thin glasses.

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[3] S. Bruns et al., "Recent developments in precision optical coatings prepared by cylindrical magnetron sputtering", Proc. SPIE 9627, Optical Systems Design: Advances in Optical Thin Films V, 96270N, 127-133 (2015); <https://doi.org/10.1117/12.2191351>

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[5] Patent: B. Galonska, DE 10 2023 102 251 B3.

[6] S. Bruns, P. Henning, T. Melzig, J. Terhürne, and M. Vergöhl, "Improving optical thickness monitoring by including systematic and process-influenced transmittance deviations ", Appl. Opt. 62, B141-B147 (2023); <https://doi.org/10.1364/AO.475076>

Target Group | Surface Engineering for Optics & Optical Components

Covered Topics | simultaneous double-side coating of optical components, thickness monitoring during optical interference coating, process control of magnetron sputtering coating machine

Session 311 | Industrial batch atomic layer deposition for optical and optoelectronic applications

Shuo Li

Afly solution oy, Espoo, Finland

Atomic layer deposition (ALD) technology has shown strong advantage of coating on 3D surface, comparing to PVD technology. This unique feature attracted lots of interesting from optical and optoelectronics industries. We successfully developed the batch ALD processes and coating systems, which were used in the mass production of the coating on 3D substrates. ALD coating shows better uniformity than PVD coating. The stability and reliability of ALD coating reached the industrial requirements. However, there is still challenge for ALD to be used in more optical applications comparing to the PVD technology, eg. higher cost of ownership, limited materials, high film stress, low film hardness and so on. Hopefully ALD community from research and industry will work together to find a solution on above challenges and enable ALD to be used more wide in the industry.

Target Group | Coating technologies for optics and optoelectronics

Covered Topics | Antireflection coating on plastic camera lens, Decorative coating on 3D glass, Passivation coating for mini-LED and micro-LED

Session 312 | Ion beam technologies for advanced surface engineering

Carsten Bundesmann, Frank Frost, Daniel Spemann

Leibniz Institute of Surface Engineering (IOM), Leipzig, Germany

Ion beam technologies are key technologies for current and future technological challenges, such as for surface engineering by (reactive) ion beam etching or for high-quality optical coatings by ion beam sputter deposition.

Ion beam technologies have been a core competence of the Leibniz Institute of Surface Engineering (IOM) for more than 50 years. The activities comprise the development of dedicated ion beam sources of different types, size and shape, including peripheral operational components, and fundamental investigations of the ion-solid interaction and sputtering process. The applications focus on (reactive) ion beam etching for surface smoothing, structuring, figuring and trimming of optical surfaces with highest precision. This paper will highlight some of these activities.

Session 313 | Industrial Ion Beam Sputtering Systems with Very Large Coating Areas

Kai Starke, Nick Erhart, Raoul Middendorff, Stefan Schrameyer
Cutting Edge Coatings GmbH, Hannover, Germany

Ion beam sputtering (IBS) is widely known as the technology to produce functional coatings that has highest reachable optical performance specifications. IBS is the reference for lowest optical losses i.e. losses in absorptance and scattering limiting the functionality of coatings in laser applications. The cleanliness and cosmetic appearance of IBS coatings in terms of particle contamination is unsurpassed and opens up ways of new applications in basic research and industry.

In recent years, the long-lasting disadvantage of relatively small areas of uniform IBS coatings has been resolved by a new generation of large box coaters. Originating from intense company internal and bilateral research together with Laser Zentrum Hannover, immense progress in IBS has been made leading to optics sizes with more than 600mm of usable diameter. During this presentation, an overview will be given on the current state-of-the-art in large-area IBS optics and near future perspectives of even larger coated objects for groundbreaking applications.

Session 314 | Sustainability in Precision coating

Sirish Chanda
Bühler Alzenau GmbH, Alzenau, Germany

As precision coating advances in complexity and demand, the supply chain and environmental impacts of special materials is more pronounced. This talk presents how Bühler Leybold Optics accelerates sustainability in vacuum coating by establishing circular pathways for few consumables like: LaB6 plasma cathodes, Hafnium sputter targets as well the common AR coating material, SiO₂. We outline a framework for materials circularity – collection, decontamination, re-processing, requalification – tailored to high purity coating applications. For LaB6, we are challenged by low tolerances in the end operation, therefore carefully controlling new and old powders to achieve equivalent end-quality. Key takeaway for evaporation materials include input feedstock assessment as well as methods for validation post recycling (like ICP, GDMS, etc). Combining process engineering with supplier partnerships, Bühler Leybold Optics is transforming end of life consumables into durable, qualified, low-waste coating operations without compromising film quality. Attendees will gain know-how into our recycling portfolio and our efforts in the background to drive sustainability forward.

October 14, 2025

Rudolf-Jaeckel-Award 2025

RJA02 | Gas discharge physics: Examples for basics, diagnostics, and applications

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Gas discharges involving surface phenomena have been studied for more than 250 years [1]. Already in the 1800s, papers were published on the use of optical emission to investigate the transition between a continuous glow discharge and an arc, the electrical structure and configuration of dc glow discharges, and the nature of metal atoms sputtered from the cathode. Classification of discharge modes was initially based on their visual appearance and later by their current-voltage characteristics. Oscillating or pulsing of power supplied, involvement of magnetic fields, effects of electrode material and geometry etc. make the situation more complicated [2]. Effects like secondary electron emission, thermionic emission, drifts in magnetic fields, gas heating, flow pattern and collision processes affect the discharge mechanisms which are important for various plasma-based applications in PVD (e.g. magnetron sputtering, HiPIMS), PECVD (e.g. plasma polymerization) or plasma cleaning and etching.

In order to optimize the related processes suitable diagnostics for the plasma bulk as well as for the sheath in front of solid surfaces are necessary. Among them methods for the flux measurement of charged and neutral species toward plasma-facing surfaces by probes which are also applicable in industry are of special interest. In addition to well-established conventional diagnostics as Langmuir probes (LPs), Faraday cups (FCs) and retarding field analyzers (RFA), also the principles of "non-conventional" diagnostics as calorimetric probes (CPs) and force probes (FPs) will be discussed [3]. These rather simple methods are useful tools for the measurement of overall, not species resolved, ions and neutral particle fluxes toward surfaces. Of particular interest is the combination of different types of probes, e.g. retarding field analyzer (RFA) and passive thermal probe (PTP). The PTP serves as collector, in front of which three centrally aligned grids are operated as the retarding field system. In such setup, the collector does not only measure the incoming ion current depending on the voltage applied to the grids of the RFA but also the incoming energy flux density of the impinging ions or neutrals, respectively. Another example is the combination of a quartz microbalance with a FP for the determination of the sputter plume by measuring the directionally resolved momentum flux of the deposited particles.

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October 15, 2025

Keynote Lectures

KN-0201 | Circular Economy in the Thin Film Industry: Opportunities and Challenges Between Regulation and Rising Customer Expectations

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Thin film technologies enable the deposition of highly functional coatings from metals, ceramics, and composites, significantly enhancing durability, corrosion resistance, and overall performance in industries such as aerospace, automotive, and electronics. Yet, the end-of-life recovery of these coatings poses substantial challenges. Their strong adhesion to substrates, minimal thickness, and increasingly complex multilayer architectures hinder efficient separation, while the relatively low material value compared to recovery costs and the risk of contamination in recycling streams further limit current options. Addressing these challenges requires a systematic approach that bridges engineering practice with sustainability targets. This keynote introduces a methodological framework designed to align bottom-up product and process decisions with top-down goals derived from an absolute sustainability perspective, acknowledging the biophysical limits of the planet. The framework provides guidance for identifying and prioritizing mitigation strategies, thereby supporting engineering decisions that advance circularity in surface engineering. Future research directions are outlined, focusing on design for recyclability, innovative delamination and separation technologies, and closed-loop recovery pathways to advance a circular economy in the thin film industry, shaped by evolving regulations and increasing customer expectations.

KN-0202 | Flexible Packaging with Compostable Materials and Enhanced Barrier Properties

Michaela Agari

BASF SE, Ludwigshafen, Germany

In today's environmentally aware market, the need for sustainable packaging solutions has never been more urgent. As the demand for eco-friendly alternatives grows, the industry is increasingly focused on the benefits of both recyclability and compostability, particularly in the food packaging sector. Compostable food packaging provides a valuable end-of-life option, but it also encounters significant technical challenges, especially when it comes to meeting the high barrier requirements necessary for maintaining product freshness and safety. This presentation will explore the cutting-edge strategies being developed to enhance the barrier properties of compostable flexible packaging specifically for food applications. We will particularly emphasize the promising use of inorganic barriers, which are compatible with compostable materials and effectively tackle issues related to moisture and oxygen permeability. By marrying these advanced barrier technologies with compostable substrates, the food packaging industry can lead the way toward more sustainable practices that do not compromise on quality or performance.

October 15, 2025

Panel Discussion “Navigating Sustainability, Resilience & Circular Economy”

What are the challenges faced by SMEs, medium-sized, and large enterprises in implementing sustainability, building resilience, and embracing circular economy principles?

This panel brings together representatives from a large corporation, a small enterprise, and a company with expertise in hazardous materials, regulatory targets, and supply chain management. Together, they will explore practical approaches, share experiences, and discuss the structural, technological, and strategic hurdles companies encounter on their path toward a more sustainable and future-proof industry.

Moderation: **Christoph Herrmann** | Fraunhofer IST, Technische Universität Braunschweig | Braunschweig, Germany

Discussion Participants:

- **Nazlim Bagcivan** | Schaeffler Technologies AG & Co. KG | Herzogenaurach, Germany
- **Richard Kallee** | G.P.A. Gesellschaft für Plasma Applikation mbH | Leverkusen, Germany
- **Ruben Wagner** | GfE Fremat GmbH | Brand-Erbisdorf, Germany

October 15, 2025

WORKSHOP »Surface meets Life science technologies«

Plasma based surface treatment processes play an important role in many areas of life science- and bio-technologies. All such surfaces share their demands on customers safety, biocompatibility, functionality, mechanical resilience and durability. Innovative approaches are needed e.g. for the development of innovative implants or sustainable processing of plant raw materials and residues, in food processing, hygiene or surface sterilization. Such plasma treatments, especially for antimicrobial surface, are not limited to bio- and med-tech applications, but may also be used for the treatment of hospital wastewater or the self-disinfection of surfaces and articles in clinical environments.

Main Topics | Implant Coatings, Plasma Surface Treatments, Additive Manufacturing, Plasma Applications, Tribology, Surfaces, Coatings, Antimicrobial, Bioeconomy, Biotechnology, Foodtechnology

Target Group | Systems and Mechanical Engineering, Surface & Microsystems Technology, Biotechnology

Tutorial Committee

- **Dr. Frank Hempel**, Leibniz Institute for Plasma Science and Technology e.V. (INP), Greifswald, Germany;
- **Dr. Canet Acikgoz**, Oerlikon Surface Solutions AG, Balzers, Liechtenstein;
- **Harald Holeczek**, MEDICOAT AG, Mägenwil, Switzerland

Session 501 | Development of novel medical implant coatings: antibacterial function and biocompatibility

Katharina Maniura¹

¹ Empa, Biointerfaces/ Materials meet Life, St. Gallen, Switzerland; ² Empa Swiss Federal Laboratories for Materials Science and Technology / ETH Zürich, Biointerfaces, St. Gallen, Switzerland

Target Group | medtech

Covered Topics | coatings and characterisation; biological studies

Session 502 | Oxygen-containing, lithographically structured and plasma-chemically modified amorphous carbon coatings

Sven Ulrich¹, Friederike D. Danneil², Michael Stueber¹

¹ Karlsruhe Institute of Technology (KIT), Institute for Applied Materials (IAM), Eggenstein-Leopoldshafen, Germany; ² Agricultural University of Iceland, Faculty of Agricultural Sciences, Borgarnes, Iceland

By means of surface engineering medical engineering products and components are optimized for their specific application. Medical engineering products, such as scalpels, stents and blood bags or surgical components like joint prostheses, get in contact with body fluids, a biological environment. In a biological environment the requirement profile of the component, besides mechanical, physical and tribological properties, is significantly governed by the reaction of the biological system after contact with and strain of the component's surface. Whether a prosthesis is accepted or a stent causes a thrombosis, primarily depends on the surface properties of the exogenous component. Carbon in its different modifications is known to be biocompatible.

In order to adjust the surface properties, with oxygen modified amorphous carbon coatings were deposited by reactive d.c. magnetron sputtering. Sputtering parameters like oxygen flow, d.c. target power or r.f. substrate bias were varied systematically. Structure of the amorphous network, composition, surface topography, surface chemistry, and other properties of the coatings were analysed by different methods. An increase of oxygen flow resulted in an increase of oxygen content in the coating and at the same time reduced the deposition rate. More sp²

hybridized carbon atoms were found with increasing oxygen flow. In order to examine the wettability, contact angles of a sessile drop of three different test liquids (distilled water, formamide and benzyl alcohol) were successfully measured. From these results the surface free energy was derived by the method of Owens and Wendt. Contact angles decreased with increasing oxygen flow, resulting in an increase of the polar component of surface free energy. Additionally, amorphous carbon coatings (single and double layered), which were plasma-chemically modified during deposition by addition of different reactive gases (H_2 , N_2 , O_2), were photolithographically structured with eight different patterns. The influence of these surface patterns – four pillar patterns and four well patterns – on the wettability was examined. The eight different patterns had very different influence on the wettability. The wettability models according to Wenzel as well as Cassie and Baxter did not satisfactorily explain the experimental results of the patterns. Therefore, both models were combined to a unified model. By this, a both models comprising function was successfully created, the models of Wenzel and Cassie-Baxter, respectively, representing a limit value.

The reaction of different components of human blood (blood plasma, platelets) was successfully tested on the oxygen containing amorphous carbon coatings. A higher polar component of surface free energy positively influenced the ratio of human serum albumin and fibrinogen (HAS/Fib) by increasing it. The results of first tests with human platelets showed a good hemocompatibility of the oxygen containing amorphous carbon coatings.

Target Group | Physicists, chemists, biologists, and medical engineers

Covered Topics | Biocompatible PVD coatings are being developed and modified so that they can be used in the medical technology sector, for example for coating tools used in medical applications, for medical components, and for implants.

Session 503 | PFAS free anti-stick coatings for superior electrosurgical performance

Noora Manninen, Klaus Boebel

Oerlikon Surface Solutions AG, Balzers, Liechtenstein

Per- and polyfluoroalkyl substances (PFAS) are a large class of thousands of synthetic chemicals currently used in a wide variety of products (e.g. food packaging, cookware, textiles, medical devices, semiconductor components, batteries, among many others). PFAS contain carbon-fluorine bonds, which are one of the strongest chemical bonds in organic chemistry, meaning they are very attractive in different consumer products as they can resist to degradation. Nevertheless, the degradation resistance also persists once they are disposed. Currently PFAS are increasingly detected as environmental pollutants and some are linked to negative effects on human health, which has led to the current restriction proposal by European Chemical Agency (ECHA).

The restriction on use of PFAS will require the development of new solutions, which must fulfill health and environmental requirements. Medical devices are one of the main fields of use of PFAS, where PTFE based coatings are widely used, among many applications as anti-stick coatings in electrosurgical devices. In the current work existing coating solutions already in use for medical market and approved by regulatory authorities (e.g. FDA) have been tested (e.g. TiN, CrN, DLC, Parylene C) and compared to new coating solutions under research and development. The main goal is to obtain coatings with good anti-stick performance, which ideally can be re-used as multiple use devices, opposed to concept of single-use devices, which are discarded after each surgery generating large amount of waste. In order to fulfill the requirements for multiple use devices the coatings must stand multiple cleaning and sterilization cycles meaning they must have good corrosion properties as well as good abrasion resistance.

In the present study the coatings are characterized regarding their surface energy given that this surface property is connected with anti-sticking properties, and also functional tests are performed in a test set-up consisting of an electrosurgical unit (ESU) where coatings anti-stick performance is tested against pork liver. Additionally, the corrosion and abrasion resistance of the coatings are evaluated under autoclave and alkaline cleaning conditions and under abrasive cleaning test condition in order to resemble the lifecycle of multiple-use electrosurgical devices.

Target Group | Researchers, Medical Industry, Material Science, Biology

Covered Topics | Medical devices, anti-stick coatings

Session 504 | Antimicrobial effect of Calcium Dihydroxide coating on Titanium surface for potential implant applications

Harald Holeczek¹, Olivier Braissant², Michael de Wild³, Jasmine Rüegg⁵, Walter Moser⁴, Philipp Gruner¹

¹ Medicoat AG, Mägenwil, Switzerland; ² University of Basel, Dept. of Biomedical Engineering, Allschwil, Switzerland; ³ Fachhochschule Nordwestschweiz, Inst. für Medizintechnik und Medizininformatik, Muttenz, Switzerland; ⁴ Atesos AG, Aarau, Switzerland; ⁵ Medartis AG, Basel, Switzerland

Orthopedic implant infections after implantation are rare but represent a significant problem for patients, surgeons, and the healthcare systems. This is because these infections cause severe and persistent pain and, in some cases, may require revision of the implant, among other things. Thus, there is strong interest in the use of antimicrobial coatings on orthopedic implants to prevent periimplantitis. Here, we investigate an electrochemically deposited Ca(OH)₂ antimicrobial coating for its potential to be used on metallic orthopedic implants. One suitable characterization method, among others, is microcalorimetry, which showed a significantly decreased growth rate of bacteria placed on a metal surface covered with Ca(OH)₂. The present results suggest that the Ca(OH)₂ coating has potential for use on metallic orthopedic implants.

Target Group | medical device manufacturer; researcher;

Covered Topics | Antimicrobial coating; antimicrobial effect; characterization of antimicrobial action; coating synthesis

Session 505 | Biological Surfaces - Therapy in Plasma Medicine

Sander Bekeschus^{1,2}

¹ Leibniz Institute for Plasma Science and Technology (INP), ZIK plasmatis, Greifswald, Germany; ² Rostock University Medical Center, Dermatology and Venerology, Rostock, Germany

Medical gas plasma technology has become a daily practice in clinical treatments of patients, especially in wound healing. Today, several medical gas plasma devices have been marketed successfully, and the efficacy of the treatment is supported by solid clinical evidence. However, mechanistically, it is less clear how gas plasma effects are being mediated. In a sense, the exposed tissue can be regarded as a biological surface that is modified through the plasma process. This presentation will outline potential scenarios on the mechanisms of action based on the latest literature in the field.

Target Group | Audience with interdisciplinary interests.

Covered Topics | The presentation will touch different areas of research and application, from biochemistry, over biology, to medicine, including fields of dermatology, oncology, immunology, and redox biology and in context with plasma science.

Session 506 | Catalytic Surfaces through Plasma Processes: Innovations for Medical Technology, Chemistry, and Environmental Applications

Michaela Müller, Jakob Barz

Fraunhofer IGB, Functional Surfaces and Materials, Stuttgart, Germany

The integration of plasma processes into surface treatment opens up new ways of producing catalytic surfaces and thus enables applications in medical technology, chemical synthesis, and environmental remediation, among others. The presentation shows innovative approaches to the use of plasma technology for the immobilization of biocatalysts and the development of photocatalytic surfaces in medical technology. Using plasma technology, plastic surfaces can be equipped with functional groups or thin functional coatings that are suitable for chemically bonding different types of catalysts. The presentation will show the production of aldehyde-, carboxyl-, and amino-functional plasma-polymer coatings to which enzymes as biocatalysts can be easily attached. The attachment of organic or inorganic photocatalysts to functionalized surfaces via a wet-chemical step is also presented. A specific example of the application of the manufactured catalyst films is their use in flow-through reactors to realize continuous chemical syntheses, for example of chiral molecules. The combination of different catalysts enables cascade reactions (a series of chemical reactions), the feasibility of which is demonstrated using specific examples.

The various functionalization and coating options for plastic surfaces using plasma processes can also be used to immobilize more complex biomolecules: This is demonstrated using the example of a biosensor.

Using PECVD (plasma-enhanced chemical vapor deposition) processes, photocatalytically active inorganic coatings based on titanium dioxide can be deposited directly at low temperatures. Their properties and possible applications are demonstrated using dental implants as an example. These technologies also offer promising approaches for reducing pollutants in the environment and improving surface properties in medical technology.

Covered Topics | Plasma technology, surface functionalization, functional coatings, immobilization of biomolecules, (bio)catalytic surfaces, medical implants, chemical synthesis

Session 507 | Tissue, Medical Device, and Diagnostic Coatings delivered via Cold Atmospheric Plasma

Liam O'Neill¹, John G. O'Donoghue²

¹ Theradep Ltd, Clonmel, Ireland; ² Theradep Ltd, Clonmel, Ireland

TheraDep has developed a novel nanoscale processing technique for the application of ultra-thin layers on medical devices, diagnostic labware, and living tissues. The process utilises an ambient plasma discharge to bind functional coatings with enhanced adhesion to a wide variety of surface types. The coatings are applied in a single step and are instantly cured in place while retaining full functionality. Coatings can be readily applied to metals such as nitinol or CoCr, as well as to balloons, guide wires, diagnostic plastics amongst other devices. The 28°C deposition temperature allows for a gentle application of therapeutic solutions for tissue repair and healing. A broad range of biopolymer and pharmaceuticals coatings and depositions will be outlined, with emphasis on further possibilities as the science develops in arenas from human health to diagnostic monitoring.

Session 508 | ALD for Biomedical Applications - Encapsulation, Sensing and Surface Modification

Dorothee Deschmann¹, Nils Boysen²

¹ Fraunhofer IMS, Business Unit Health, Duisburg, Germany; ² Fraunhofer IMS, Technology, Duisburg, Germany

Atomic Layer Deposition (ALD) is an elementary key technology for a plethora of medical applications. Due to a wide availability of materials and possible combinations, layer properties can be perfectly adapted for target applications. Due to the extreme conformal deposition of ultra-thin layers in the nm range, layer stacks can be applied, for example, as encapsulation for extremely miniaturized active implants. Sensory properties can be used, to measure moisture or pH level. The sensitivity can be particularly achieved here with a very large surface-to-volume ratio, which is especially the case for 2D materials, deposited by ALD. By combining sensory with passivation layers, a hermetic, three-dimensional encapsulation can be fabricated that monitors its function autonomously. ALD layers are also used for biofunctionalization and can optimize the hydrophilicity of surfaces. At Fraunhofer IMS, conductive nanoneedles were fabricated using ALD, which can perform electrophysiological measurements in living cells as well as fluidic contacts into cells. All in all, this presentation should give a comprehensive overview about the possibilities with ALD coatings for biomedical applications.

Target Group | Medical Implant Manufacturer; Bio-Sensor Manufacturer; R&D Partner in the MedTech field

Covered Topics | Encapsulation of implants; Surface modification concerning biocompatibility / hydrophilicity / ...; Adding special, customized sensing layers

Session 509 | Arc coatings of orthopedic implants: The potential of multiphase nitride coatings

Henry Dempwolf¹, Christos Pernagidis², Thomas Vartianen², This contribution will be held by DOT on behalf of Avaluxe.

¹ DOT GmbH, Engineering, Rostock, Germany; ² Avaluxe GmbH, Nürnberg, Germany

Motivation

- What's state of the art for implant coatings?
- What are the applications of those coatings?
- Where's space for improvements?
- Are there promising coatings under development?

How to tailor medical coatings

- Ionization yield
- Alloyed targets vs. Co-Sputtering
- What's applicable in industrial scale processes?
- Arc vs. HiPIMS for coatings on implants – Where are the limitations

Characteristics of multiphase coatings

- XRD & Phase stability
- Mechanics
- Deposition rate
- Micro structure

Target Group | Persons, who interested in medical coatings and their applications

Covered Topics | Application of nitride coatings in medical products state of the art and future ; Arc processes in industrial scale production; Limits of current processes and potential for improvement

Session 510 | Biocompatible HiPIMS coatings for mold making

Konrad Bienk¹, **Christoph Schiffers**²

¹ CemeCon Scandinavia A/S, Management, Hinnerup, Denmark; ² CemeCon AG, product management coating equipment, Würselen, Germany

Plastic injection moulding is a multi-billion Euro market. A huge proportion is containers and cans for food packaging and medical consumables such as syringes and injection systems. Today's pens for insulin and other drugs are rather complex devices made of several small and very small parts requiring extreme precision. Safe and precise dosing of the liquids is a must and high-quality products with extreme reproducibility are necessary.

Complicated and precise injection moulds are the workhorses powering the innumerable number of plastic objects in our daily life. High precision, reduced wear, preservation of surfaces and quick demoulding are key requirements. PVD coatings are widely used to improve the efficiency of the demoulding process. Biocompatibility of the coating material is key to most applications since the mould is in direct contact with the molten plastic.

Tests and methods will be presented which have been used for checking and approving the biocompatibility of HiPIMS coatings for plastic injection moulding. This project focused on defining an approval route which is doable for a PVD coating production with all the limits and constraints of a commercial job coating production. HiPIMS technology was used for depositing the films. The HiPIMS method combines favorable properties for best demoulding such as smooth films without droplets with superb adhesion to the substrate and a very dense morphology of the coatings.

HiPIMS coatings are used to improve productivity in the medical industry, while keeping the extreme quality standards. The application of PVD coatings is a cost-effective solution for optimization and improvement of injection moulding processes, while ensuring all requirements for biocompatibility are met.

Session 511 | Advanced CVD Coatings: Innovations in Functional Surface Engineering and High-Performance Barriers

Andreas Hogg

Coat-X AG, La Chaux-de-Fonds, Switzerland

Coat-X offers advanced surface functionalization solutions, including hydrophobic and hydrophilic coatings, low-friction treatments, and enhanced adhesion and barrier layers, all designed to optimize device interaction with biological tissues and environments. These functional coatings improve biocompatibility, enhance reliability, and extend the lifespan of medical instruments and implants.

Building on these capabilities, Coat-X, a Swiss technology leader in thin-film encapsulation, provides state-of-the-art chemical vapor deposition (CVD) coating solutions, engineered for critical protection and miniaturization of components in medical and industrial applications. Our innovative multilayer encapsulation technology delivers ultra-hermetic coatings with thicknesses in the micrometer range, safeguarding delicate components such as MEMS, sensors, magnets, and electronics against corrosion and moisture, even in harsh environments.

Replacing traditional metal or glass encapsulation methods, Coat-X applies nanometer-scale multilayer films that combine Parylene with ceramic layers. This hybrid architecture enables significant device miniaturization and cost reduction while providing superior barrier performance, up to 2000 times greater than conventional Parylene coatings. The coatings are deposited seamlessly at room temperature, even on complex 3D geometries, ensuring unmatched versatility and precision.

Extensive validation according to industry standards, including MIL-STD-883 helium leak testing and ASTM F1249 water vapor transmission testing, demonstrates long-term durability with extremely low water vapor transmission rates, reaching as low as 2×10^{-5} g/m²/day for 5 µm-thick multilayers. This breakthrough encapsulation technology establishes new benchmarks in functional surface engineering, delivering high-performance barriers that are essential for next-generation medical devices and advanced industrial systems.

Session 512 | Chip based Biosensors – Challenges to thin-film technique

Steffen Zietzschmann

SAW COMPONENTS Dresden GmbH, Dresden, Germany

The world of biosensing and analytics is looking for new technologies. Traditional optical methods are supplemented by chip based technologies. This enables new approaches especially for POC (point of care) diagnostics. In R&D and production manifold challenges to surface engineering appear with these new requirements. The presentation gives an inside view to the first experiences. The usage of thin film technologies from chip to the interface for biological assays is considered.

October 15, 2025

WORKSHOP »Sustainability & Flexible Substrates«

Flexible materials are ubiquitous companions in our daily lives. We encounter them in many technical devices, but also in packaging of all kinds. In most cases, a coating of the surface is necessary to give the material the properties that make it suitable for an application. Against this background, the understanding and further development of coating technology plays a decisive role in the development of new products.

The issue of sustainability is very important in this context. In almost all cases, the avoidance of additional waste or microplastics is a key development goal. The focus here is primarily on the use of mono-materials in food packaging. This facilitates the transition to a circular economy.

Particular attention is being paid to the class of perfluorinated and polyfluorinated alkyl substances (PFAS). Intensive research is being carried out worldwide into ways of substituting these substances. The aim is to prevent them from permanently accumulating in the environment due to their high stability.

The workshop will focus on novel coating technologies that can make a significant contribution to solving the problems at hand, and the scaling of these technologies to industrial roll-to-roll processes.

Next to (food) packaging, applications in photovoltaics, the energy management of buildings, liquid and air filtration, and outdoor textiles will also be addressed. Here too, coated flexible materials play an important role and contribute to finding sustainable solutions.

Tutorial Committee

- **Dr. Matthias Fahland**, Fraunhofer Institute for Electron Beam and Plasma Technology FEP, Dresden, Germany
- **Filip Legein**, Europlasma NV, Oudenaarde, Belgium

Session 601 | From Trial-and-Error to Digital Twins: How AI & Simulation help to Solve Common Challenges in Roll2Roll and Inline Systems

Kristína Šástná (Tomanková), Martin Kubecka, Petr Bilek, Adam Obrusnik
PlasmaSolve, Brno, Czech Republic

Large area coaters - roll-to-roll (R2R) and inline systems - are widely used in industrial production of functional coatings – for example for barrier coatings, foil functionalization, architectural glass, or photovoltaics. The emerging trends in the industry involve, for example, coatings for energy applications (battery, electrolysis), new semiconductor applications, and conversion of 2D inline coaters to 2.5D substrates (curved glass). These new use cases require a solid understanding of the underlying mechanisms and precise control of process conditions to ensure film uniformity and process stability. In practice, recurring issues often arise during development and operation, requiring targeted troubleshooting.

Common challenges in large-area coating processes include achieving consistent film properties and coating uniformity across the full substrate area, maintaining stable process conditions, and ensuring efficient material usage. Issues such as thickness variations, plasma instabilities, or underutilized precursors can directly affect product quality and production costs.

Physics and chemistry models prove to be a highly efficient tool for understanding and troubleshooting large area coating processes, reducing the experimental work by up to 70–90%, which translates to significant cost savings, development speed up, or both. Such models can be effectively used to design both the coater hardware and the coating recipes in a targeted manner. Based on the most recent learnings from the academic sector, PlasmaSolve has developed several simulation tools applicable to different R2R and inline systems. These models predict key process traits such as deposition rate, film composition or substrate heat load, providing insight into how process settings affect

the outcome. Different model types – ranging from gas flow and chemistry models to full plasma models – can be coupled to obtain a comprehensive view of the system and guide optimization efforts.

In many cases, physics and chemistry models alone are sufficient to guide the coater design and optimization of process conditions. However, to build a complete picture of the process – including the resulting coating properties (such as hardness, density, or contact angles) – AI and machine learning (ML) is integrated into the workflow, creating digital twins of industrial processes. ML based on a limited set of experimental data complements physics and chemistry-based models by bridging the gap between plasma properties and the growing material properties. This approach combines the strengths of simulation and data-driven methods, extending the predictive power of digital process design.

Target Group | Technical experts and managerial staff working in companies that manufacture coating equipment or operate thin film production lines. This group typically faces challenges in maintaining reproducible processes, ensuring uniformity and coating quality, and improving efficiency across PVD, PECVD, and other plasma-based technologies. They are responsible for evaluating new methods and tools that can enhance process stability, reduce development cycles, and support industrial-scale implementation of advanced materials.

Covered Topics | Plasma simulation, Digital twins, Process modeling and optimization, R2R and inline systems, Thin film uniformity, PVD / PECVD process control, Simulation-based equipment and recipe design, AI integration in process engineering, Process upscaling

Session 602 | Flexible Energy: Printing Perovskite Solar Cells In Northern Finland

Thomas M. Kraft, Riikka Suhonen, Kaisa-Leena Väisänen, Antti Nurmesjärvi, Ville Holappa, Marja Välimäki, Mari Ylikunnari
VTT Technical Research Centre of Finland Ltd., Sensing Solutions, Oulu, Finland

Printed perovskite solar cells with carbon electrodes are a promising candidate for customized free-form flexible photovoltaic (PV) modules due to their solution-based processing and potential for high efficiency. Through a direct printing process for a single junction PV device flexible energy harvesting surfaces can be made for multiple applications. Advances in stability, performance, and roll-to-roll processing methods suggest potential for mass production and innovative applications (i.e. BIPV, IoT, and wearables). This includes new integration techniques such as hybrid electronic systems and injection overmolding for structurally integrated photovoltaics.

At VTT Technical Research Centre of Finland Ltd., there is significant activity in the field of printed and flexible perovskite photovoltaics. Ambitions are enhanced, not only based on the future outlook of the technology, but also as the EU's total solar power capacity is growing close to 100 GW within the decade. In fact, the use of perovskite-based photovoltaics (Pk-PV) will contribute significantly towards the overall mix of solar energy more than its peers due to its (i) low-cost (levelized cost of energy (LCOE) around €0.4 per kWh), (ii) excellent power-to-weight performance (~30W/g) and (iii) high power conversion efficiency (PCE) over 27% at lab-scale.

Furthermore, to develop efficient charge extraction within the Pk-PV cells, the processing of the electron and hole transport layers (ETL and HTL), the perovskite active layer, and the back contact electrode is studied in the n-i-p architecture. As an alternative to laser patterning, gravure printed ETL and HTL (i.e. tin oxide [SnO₂] and poly-3-hexylthiophene [P3HT]) layers were investigated for deposition on the R2R wet etched indium tin oxide (ITO). Devices made with the one-step gravure printed perovskite layer sandwiched between the ETL and HTL, can approach 10-20% power conversion efficiency with layers processed under ambient conditions. Furthermore, a sub-arctic outdoor test setup is available at VTT Oulu customized for outdoor printed PV testing. The extreme climate condition characterization can provide valuable information about the deployment in dark winter and bright summer conditions and the associated degradation effects (i.e. -35 °C to +35 °C). As the yield and performance of the R2R process is improved with material, ink, and process tuning; so will the opportunities for system integration and exploitation. For example, VTT has explored their use in architectural elements, light positioning systems, and energy modules. Opening up opportunities for flexible PV in applications for BIPV, indoor monitoring and smart packaging.

Target Group | material suppliers; PV companies; end users; researchers and academics

Covered Topics | printing perovskite solar cells with carbon electrodes on flexible substrates; R2R volume manufacturing; sub-arctic outdoor; testing and improvements in device stability; flexible PV integration in systems; sustainable nature of energy autonomous systems

Session 603 | High-efficient and coloured PV with “MorphoFlex”: a novel approach for aesthetic and freedom of design solar cells.

Stefan Hinze¹, Leon Fels¹, Thomas Kroyer², Martin Mattenheimer²

¹ ROWO Coating GmbH, Herbolzheim, Germany; ² Fraunhofer Institute for Solar Energy Systems ISE, Freiburg, Germany

The aim within the MorphoFlex project was to make affordable and highly efficient colored PV modules possible. Aesthetics and freedom of design are essential aspects for the required massive expansion of building-integrated photovoltaics. The development of a colored film based on the morpho butterfly effect that can be integrated into PV modules in a variety of ways without significantly reducing their performance will be shown. A combination of light-scattering surface and interference filter produces a color impression that is stable at any angle. The technology was developed and realized in large-scale roll-to-roll processes and integrated into PV modules.

In addition to the primarily identified application of aesthetically enhancing conventional modules, the realization of colored layers on film substrates opens up further fields of application for innovative lightweight modules or specially shaped modules, e.g. for car roofs or curved facade elements.

Target Group | ROWO Coating GmbH is a German contract roll-to-roll coating company with more than 30 years of experience in thermal evaporated and sputtered films.

The target group of ROWO Coating and the coloured OPV films are stakeholders and industry partners, which are working in the PV-related industry and which are focussed in the integration of OPVs into buildings, cars and many further applications and which are looking for a scale-up company for PVD coated films.

Covered Topics | Thin-film sputtering on polymer films for PV applications

Session 604 | R2R NET: Combining Roll-to-Roll Technologies for Sustainable Surface Functionalization of Flexible Substrates

Filip Legein

RTR NET, Dresden, Germany

Introduction of R2R NET, a network of stakeholders in roll-to-roll technologies for surface functionalization of flexible substrates. Exploration of technology combinations that can replace fluorocompounds in making flexible materials water and oil repellent, e.g., by combining surface texturing with ultra-thin coating.

Target Group | Providers and users of roll-to-roll technologies for surface functionalization. Stakeholders who are looking for halogen-free solutions to induce omniphobicity on flexible substrates.

Covered Topics | Introduction of R2R NET, a network of stakeholders in roll-to-roll technologies for surface functionalization of flexible substrates. Exploration of technology combinations that can replace fluorocompounds in making flexible materials water and oil repellent, e.g., by combining surface texturing with ultra-thin coating.

Session 605 | Advancements in roll-to-roll deposition of nanocoating by plasma enhanced chemical vapor deposition: Applications and Characterizations

Nicolas Vandencastele, Alessio Quadrelli, Jocelyn Viard

Plasmalex, Fuveau, France

In this presentation, we'll showcase the latest advance in industrial scale nano coating by plasma polymerization. Our discussion encompasses both vacuum and atmospheric plasma deposition methods, offering a comprehensive overview of these cutting-edge technologies. We begin with a technical introduction that explains the operating principles of atmospheric and vacuum plasma. This segment highlights the distinct technological differences and specificities of each method.

The core of our talk centers on the diverse applications of these nanocoating. We will showcase a range of implementations, for some of them accompanied by a scientific and/or technical characterization of the coatings. Among the featured applications are release coatings, which are integral to casting and transfer processes as well as hydrophobic and hydrophilic coating on membrane/filtration media.

Our aim is to provide attendees with a clear understanding of the latest advancements in plasma-deposited nanocoating, highlighting their multifaceted applications and the scientific principles underpinning their development and use.

Session 606 | Process development of multi-layer dielectric and barrier solutions for energy and sustainable applications

Elizabeth Josephson

Intellivation LLC, Loveland, USA

Development of multi-layer dielectric and barrier solutions play a key role in the advancement of sustainable and renewable energy technologies. Using vacuum coating processes, multi-layer structures and barrier coatings enable unique material properties for applications in energy storage, electronic devices, aerospace and environmental protection. Key methodologies include precision layer deposition, advanced patterning capabilities, in-situ capabilities for improved analysis of a wider range of materials, and scalable manufacturing processes. Applications span across thin-film photovoltaics, multi-layer optical film stacks, high-performance capacitors, protective coatings for renewable energy systems, barriers for multiple applications, including OLED's and insulation or shielding technologies that enhance device longevity, efficiency and performance. se solutions contribute to the evolution of sustainable energy systems and environmentally friendly solutions.

Session 607 | OES-Driven Process Monitoring and Control Enables Long-Term Stability of Industrial Roll-to-Roll HiPIMS Coatings

Thomas Schütte¹, Yao-Kuang Yang², Ralf Bandorf³, Tzu-Hou Chan⁴, Ping-Yen Hsieh^{5,6}, Ying-Hung Chen^{5,6}, Ju-Liang He^{6,5}

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As specifications for thin film coatings on flexible substrates become more and more demanding, high production yields and cost effective production are major factors in this competitive market. These goals drive the demand for efficient process monitoring and control systems. Optical emission spectroscopy (OES) is a key technology for in-situ and real-time process monitoring and control in industrial application as it is non-invasive and rather easy to integrate in a coating machine.

In a collaborative project of Taiwanese and German partners, it was demonstrated that active process control stabilizes production and product quality: The OES technology was established at a HIPIMS Roll-to-Roll coater for continuous coating of Cu on flexible PET polymer substrate. With an active feedback control loop for stabilizing the ionization degree of Cu⁺ to Cu, long-term stability of the process and thus the film quality is achieved.

Target Group | Engineers, scientists and designers of coating processes and industrial coating machines

Covered Topics | OES based process monitoring and control; HIPIMS Roll-to-Roll coater for Cu films on PET substrates; Active OES driven process control for long-term stabilization of process and product quality

Session 608 | Requirements for the sustainability of a mechanical engineering company using the example of a roll-to-roll vacuum coating system

Michael Mücke

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Mechanical engineering companies are faced with diverse and challenging requirements regarding their consumption of the energy and material resources available worldwide. The requirements for this sustainability begin with the environmentally friendly production of the systems but must also consider the selection of the materials used. For the company's customers, the environmentally friendly consumption of auxiliary materials and low energy requirements of the systems are important. These parameters are considered in order to ensure the company's classification in an international comparison. Using a system from the market segment "roll-to-roll vacuum coating systems" of a globally operating group of companies in the mechanical engineering sector, the topic will be worked through based on practical solutions and discussed in the lecture.

Session 609 | Functionalisation of Surfaces with Nanometre-thin Carbon Nanomembranes

Albert Schnieders

CNM Technologies GmbH, Bielefeld, Germany

Carbon nanomembranes (CNMs) [1] are a molecular-thin, carbon-based 2D-sheet material. Their properties (dielectric, easy chemical functionalisation, intrinsic porosity, ...) are more comparable to ultrathin polymer films than to atomically thin graphite like the complementary and better known 2D material graphene. CNMs are produced by electron beam-induced cross-linking of thin layers of aromatic molecules. A variety of production methods are possible - from large-area CNM composite membranes for industrial-scale filtration, to coatings for modifying any type of surface (metals, semiconductors, polymers, etc.) and CMOS-compatible integration into components. Applications can be found in sensor technology, energy technology, semiconductor production and especially in filtration and separation.

[1] A. Turchanin, A. Götzhäuser: *Advanced Materials* **28** (2016) p. 6075-6103

Target Group | Research and development: scientists, developers, engineers, business development

Covered Topics | Membrane technology: water filtration (low-pressure reverse osmosis, forward osmosis); Energy technology: separators for next generation batteries, proton exchange membranes (barrier to reduce fuel - especially hydrogen - cross over; Surfaces: barrier and/or corrosion protection; Sensor technology: functionalisation of surface sensitive sensors; Semiconductor production: ultrathin dielectric layer, area selective deposition, EUV pellicles.

Session 610 | Plasma Meets Nanofibers: Advanced Surface Treatment for High-Performance Membrane

Jana Baráková, Ivan Ponomarev, Vojtěch Hýbl

Elmarco s.r.o., Liberec, Czech Republic

Electrospun nanofiber membranes are widely valued for their high surface-area-to-volume ratio and tunable porosity, making them attractive for applications in protective clothing, waterproof breathable fabrics, and advanced barrier materials. However, many electrospun polymers exhibit limited intrinsic hydrophobicity, which can restrict their effectiveness in moisture-repelling or outdoor environments. This work explores the fabrication of fully hydrophilic nanofiber membranes from a polyamide copolymer using high-throughput needleless electrospinning technology, followed by surface modification with a roll-to-roll plasma-enhanced chemical vapor deposition (PECVD) system to improve waterproofness. An ultra-thin (< 50nm) conformal coating based on siloxane chemistry was deposited onto the fiber surface. This fluorine-free

plasma coating reduces surface energy to approximately 20 mN/m, resulting in a highly hydrophobic surface without compromising fiber structure or breathability. Waterproofness was evaluated by water column testing, with treated membranes achieving a hydrostatic resistance of up to 10 meters of water column (10 mWC). The results demonstrate that PECVD with fluorine-free siloxane precursors is an effective, sustainable method for tuning nanofiber surfaces for advanced waterproof and breathable applications.

Session 611 | Fabrication of Sustainable PFAS Free polymeric Films and Membranes.

Angelos Zeniou, Lefteris Manouras, Zeta Stavromitrou, Evangelos Gogolides
NCSR Demokritos, INN, Athens, Greece

Vacuum plasma and coating technologies have emerged as transformative tools for engineering materials with tailored surface properties, providing a robust platform for innovation in membrane science. These technologies enable precise modification of surface topographies and chemistries at the nanoscale, offering control over the physicochemical attributes of materials. In this study, we introduce a novel methodology for plasma nanotexturing of membranes that holds the potential to revolutionize the field by addressing longstanding environmental and performance challenges.

The plasma nanotexturing process involves nanoscale structuring of membrane surfaces to achieve superhydrophobicity and oleophobicity while enhancing resistance to wetting, fouling, scaling, and chemical degradation. These advancements are achieved without the use of per- and polyfluoroalkyl substances (PFAS) compounds, which are increasingly regulated due to their persistence in the environment and associated health risks. By eliminating PFAS from the material composition, this technology not only mitigates environmental and health concerns but also aligns with global sustainability and regulatory imperatives.

A key feature of this methodology is its ability to achieve advanced functionalization without compromising the mechanical stability or scalability of the membranes. This scalability ensures that the technology can meet industrial production demands, making it a viable alternative to traditional membrane manufacturing methods. The combination of performance enhancement and environmental responsibility positions this technology as a cornerstone for next-generation membrane solutions.

In conclusion, the integration of vacuum plasma and coating technologies with innovative nanotexturing methodologies offers a powerful approach to creating advanced, PFAS-free membrane materials. This advancement not only addresses pressing environmental and health challenges but also sets new benchmarks for membrane performance across diverse applications, paving the way for a more sustainable and efficient future in material science and engineering.

References:

- Zeniou, A.**, Smyrnakis, A., Constantoudis, V., Awiuk, K., & Gogolides, E. (2021). One-Step Control of Hierarchy and Functionality of Polymeric Surfaces in a New Plasma Nanotechnology Reactor. *Nanotechnology*, 32(23), 235305.
- Zeniou, A.**, Manouras, E., Ioannou, D., & Gogolides, E. (2024). Superhydrophobic and Oleophobic Nylon, PES, and PVDF Membranes Using Plasma Nanotexturing: Empowering Membrane Distillation and Contributing to PFAS-Free Hydrophobic Membranes. *Micro and Nano Engineering*, 24, 100269.
- Zeniou, A.**, Smyrnakis, A., Constantoudis, V., Awiuk, K., & Gogolides, E. (2021). One-Step Control of Hierarchy and Functionality of Polymeric Surfaces in a New Plasma Nanotechnology Reactor. *Nanotechnology*, 32(23), 235305.

Target Group | This work is aimed to target professionals, researchers, and decision-makers involved in material science, membrane technology, and environmental sustainability. This includes engineers and scientists specializing in water treatment, medical filtration, and industrial process optimization, as well as stakeholders in industries requiring advanced membrane solutions, such as pharmaceuticals, chemical manufacturing, and energy production.

Covered Topics | This work covers topics related to vacuum plasma and coating technologies, focusing on their transformative role in material science and membrane engineering. It details the methodology of plasma nanotexturing for precise nanoscale surface modification, enabling the development of advanced PFAS-free and fluorine-free membranes with enhanced physicochemical properties, such as superhydrophobicity, oleophobicity, and resistance to fouling and chemical degradation. The discussion highlights the applications of these membranes in water

treatment, and industrial processes, emphasizing their superior durability, efficiency, and scalability compared to conventional alternatives. Additionally, the text addresses critical environmental and health concerns associated with PFAS and fluorinated compounds, positioning this technology as a sustainable solution that aligns with evolving regulatory frameworks and industry demands while paving the way for future innovation in high-performance membrane materials.

Session 612 | Thermochromism: Fabrication, Properties, and Applications of Sputtered VO₂ Films

Cindy Steiner, Matthias Fahland

Fraunhofer FEP Dresden, R2R technologies, Dresden, Germany

Thermochromism refers to the property of materials to modify their optical characteristics in response to temperature changes. Vanadium dioxide (VO₂) is a promising material for thermochromic applications, as it exhibits a phase transition from an insulating to a metallic state at a critical temperature of approximately 68 °C. An overview of current research directions and technological developments will be discussed, aimed at further improvement of the properties and applicability of VO₂ films. Current research results will be presented, characterizing the structural and optical properties of reactively sputtered VO₂ films. Additionally, practical implementation possibilities will be provided.

Covered Topics | thermochromism; reactive magnetron sputtering; roll-to-roll-technologies

October 15, 2025

IGF-Sessions »Innovation with Collaborative Research«

The EFDS drives innovation in the thin film industry by initiating and coordinating projects within the German funding program “*Industrielle Gemeinschaftsforschung (IGF)*”. This unique program empowers small and medium-sized enterprises (SMEs) to explore new technologies and product ideas at a pre-competitive, application-oriented level. Guided by the expertise and practical input of SMEs, research institutions work on forward-looking topics and transfer the results directly into industrial practice – strengthening competitiveness and paving the way for global success.

In this session, you will discover how IGF creates real added value: from national to international perspectives, from cutting-edge project results to concrete opportunities for participation. Learn how SMEs benefit from collaborative research and how you can become part of this innovation network.

Collective industrial research projects (#IGF) are funded by the Federal Ministry of Economics and Energy (BMWE) based on a resolution of the German Bundestag.

Session 401 | Researching together, growing stronger: innovation through cooperation in the SME sector

Katrin Ferse, Thomas Schütte, Florian von Appen

EFDS e.V., Dresden, Germany; PLASUS GmbH, Germany; Cornet - Collective Research Networking, Germany

This opening talk introduces the funding program “*Industrielle Gemeinschaftsforschung (IGF)*” – Industrial Collective Research – which enables SMEs to collaborate closely with leading researchers and research associations to drive innovation at a pre-competitive level. Beyond the national framework, the program also opens doors to international cooperation. The EFDS plays a key role in supporting these initiatives by helping to establish project consortia, coordinating the execution of research projects, and ensuring effective knowledge transfer to industry after project completion.

Mr. Florian von Appen from the CORNET Team will present the international dimension of IGF and highlight opportunities for cross-border collaboration. In addition, Mr. Thomas Schütte from PLASUS GmbH will share the perspective of an innovative SME actively engaged in EFDS expert committees and IGF projects, illustrating how companies can benefit directly from collective research.

Further information to CORNET: https://cornet.online/EN/Home/Home_node.html

Further information to IGF: <https://portal.industrielle-gemeinschaftsforschung.de/>

Session 402 | Enhanced Corrosion Behavior of TiAlN Coatings through MgGd Additions

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This study investigates the corrosion resistance of novel PVD coatings by alloying TiAlN with MgGd. In a previous work, the authors employed the alloying concept for TiN: By alloying MgGd with the binary coating system TiN, an outstanding corrosion resistance of up to 1000 hours in the neutral salt spray test (NSS test) was achieved. Additionally, it was shown that TiMgGdN coatings exhibit corrosion resistance in alkaline solutions. The corrosion protection was attributed to several factors, such as the hydrophobic effect, chemically inert passivation layers, and defect tolerance. Due to the outstanding corrosion resistance of the MgGd-alloyed binary TiN coating systems, this study aims to extend the alloying concept to ternary coating systems. Therefore, in this study, the corrosion resistance of TiAlN + MgGd and TiN + MgGd coatings will be analyzed and compared. The influence of the Al/ Mg ratio on the microstructural characteristics, coating hardness, and passivation layer was examined using various methods, including Scanning Electron Microscopy (SEM), X-Ray Diffraction (XRD), and X-Ray Photoelectron Spectroscopy (XPS). The chemical composition of the investigated coatings was determined using Glow Discharge Optical Emission

Spectroscopy (GDOES) and Energy Dispersive X-ray Spectroscopy (EDX). Corrosion properties were evaluated in neutral, alkaline, and acidic environments through the NSS test and potentiodynamic analysis. The study will demonstrate the enhanced corrosion resistance of the TiAlMgGdN coating compared to the TiMgGdN coatings. The results show that addition of Al enhances corrosion resistance through the formation of a chemically stable Al_2O_3 passivation layer. Al also contributes to the formation of a compact and dense coating microstructure. As a result, TiAlMgGdN coatings demonstrated superior corrosion properties in comparison to TiMgGdN, especially in acidic electrolytes.

Target Group | This study is primarily aimed at materials scientists and engineers who specialize in corrosion protection, surface engineering, and coating technologies. It is also relevant to researchers working in the field of thin film deposition and PVD coatings, particularly those exploring innovative alloying concepts for enhanced material performance. The study may also benefit students and PhD candidates in materials science, who are engaged in the development of advanced surface technologies with a focus on corrosion resistance. Lastly, industrial partners and developers looking to implement high-performance, corrosion-resistant coatings in real-world applications will find the results valuable for practical innovation.

Covered Topics | The study addresses key aspects of advanced surface engineering, focusing on the development of corrosion-resistant PVD coatings. It investigates the effect of alloying TiAlN with MgGd on coating performance, particularly corrosion behavior. The study explores the impact of Al/Mg ratio variation on microstructural characteristics, hardness, and passive film development. A combination of analytical techniques, including SEM, XRD, XPS, GDOES, and EDX, is used to characterize the coatings. Corrosion resistance is evaluated under neutral, alkaline, and acidic conditions using NSS and potentiodynamic test. The study further discusses the underlying protection mechanisms such as hydrophobicity, chemically inert passivation layers, and defect tolerance.

Session 403 | Development of Tribologically Optimized Tool Surfaces for the Cost-Efficient Forming of High-Strength Ti(Al) Alloys at 750–1250 °C

Markus Mejauschek¹, Daniel Templin¹, Matthias Demmler², Jürgen Heidrich²

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The IGF research project TiAlHighEnd focused on the cost-efficient high-temperature forming of high-strength titanium aluminide alloys in the temperature range of 750 to 1250 °C—an application area with particularly high demands on the thermomechanical stability and functionality of the tool materials used. The project centered on the development and optimization of innovative material solutions and advanced surface treatments to significantly improve the service life and performance of the forming tools. For the lower temperature range, established nickel-based (Nimonic 75) and cobalt-based alloys (Stellite 21) were evaluated. At elevated temperatures up to 1250 °C, molybdenum-based materials (TZM, MHC) were employed. Targeted modification of the tool surfaces through gas boriding, plasma nitriding, and diffusion alloying resulted in a substantial increase in surface hardness to values above 2000 HV, as well as a significant reduction in the coefficient of friction to values below 0.1. Additionally, oxidation-resistant aluminum diffusion coatings were applied to further enhance high-temperature performance. To enable process-relevant evaluation of these approaches, a novel high-temperature press was developed and successfully commissioned, allowing forming trials at temperatures up to 1250 °C. Systematic analysis using ring compression tests under inert gas atmosphere already demonstrated promising tribological behavior and a significant increase in tool life during the project phase. The results of the TiAlHigh-End project provide scientifically validated findings and valuable impetus for the industrial application of forming technologies for high-temperature-resistant materials. They make an important contribution to process and resource efficiency in high-performance manufacturing.

Target Group | Manufacturers of high-temperature forming tools; R&D departments in aerospace and automotive industries; Material scientists and surface engineers; Suppliers of tool steels and refractory alloys; Engineering companies in hot forming technology

Covered Topics | High-temperature forming of Ti(Al) alloys; Tribological optimization of tool surfaces; Surface treatment methods: gas boriding, plasma nitriding, diffusion coatings; Tool material evaluation: Ni-, Co-, and Mo-based alloys

Session 404 | ResilTex – How to Identify and Improve Organisational Resilience? A Process Model for SMEs in the Textile and Clothing Industry.

Thomas Fischer, Marcus Winkler, The ResilTex project (01|F22895N) was funded by the Federal Ministry for Economic Affairs and Energy as part of the Industrial Collective Research (IGF) programme on the basis of a resolution passed by the German Bundestag.

DITF Denkendorf, Management Research, Denkendorf, Germany

The onset of the coronavirus crisis clearly demonstrated how vulnerable value creation is, especially in multi-stage and fragmented global value chains. It was almost impossible to respond quickly and successfully to such unexpected disruptions. Supply chains collapsed and the market could no longer be served. To avoid this in the future, resilient companies are needed in the fragmented, SME-dominated textile and clothing industry.

As main part of the project, a process model was developed at the Centre for Management Research at DITF Denkendorf to help companies identify and improve their own organisational resilience. This is done by using a self-assessment tool (SAT), which, according to the identified result, also suggests company-specific measures to strengthen organisational resilience. These measures then can be selected and designed individually. In addition, support is offered for the implementation and monitoring of the measures in the companies.

Target Group | With this innovative toolkit, small and medium-sized companies in the textile and clothing industry receive suitable guidelines and examples for a consistent and efficient approach to assessing and improving the resilience of their value creation.

Covered Topics | This project took the current situation and the heterogeneous structure of value creation in the textile and clothing industry as its starting point to develop a specific questionnaire that refers to the various levels of resilience within a company: value creation, employees and learning, as well as infrastructure. This questionnaire was implemented as a self-assessment using an online tool that determines organisational resilience by using appropriate assessment scales, evaluation rules and formats, and also identifies measures for improving it. Each of these downloadable measures was described on approximately four pages, with an overview assessment of financial and personnel costs, the time frame required and the impact, with suggestions for implementation, the knowledge required on the part of the company, promoting and inhibiting factors, key figures and a practical example.

Session 405 | Development of manufacturing process sequences for coated metallic bipolar plates used for fuel cells of the highest quality and energy efficiency

Maurizio Giorgio¹, Niels Fredebeul-Beverungen¹, Teja Roch¹, Stefan Polster², Sebastian Porstmann², Christian Kipp³, Martin Keuneke³

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Cost-intensive production processes limit the application of PEM fuel cells. The aim of the project is to develop new manufacturing routes for metallic bipolar plates (BPP) through the combination of different coating approaches and forming processes such as hollow embossing and hydroforming.

Target Group | One approach involves carbon layer systems produced by arc deposition and magnetron sputtering; which maintain high electrical conductivity and corrosion resistance after forming. Another separate approach uses pre-coated plates that are functionalized after forming through plasma diffusion to minimize defects. The results show that by using arc deposition, the target values of the DOE can be achieved even with thin layers (approx. 50 nm) and low temperatures. For sputtered layers, a compromise between corrosion stability and contact resistance is necessary. The test results from hydroforming (HBU) with an initial sheet thickness of 100 µm indicate that the forming process was successful. The formed channels were divided into different regions to analyse deviations from the target geometry. The formed BPP were subsequently provided for coating analysis. These investigations aim to develop a cost-effective, efficient, and scalable production process for metallic bipolar plates to promote the application of PEM fuel cells.

Covered Topics | IGF 20/11 22948 BG

Session 406 | Trade-Off Between Contact Resistance and Electrochemical Corrosion Behavior in Low-Temperature Plasma-Nitrided Metallic Bipolar Plates

Caroline Karina Chandra¹, Magnus Salvador², Rüdiger Reitz¹, Holger Hoche¹, Peter Kaestner², Günther Bräuer², Matthias Oechsner¹

¹ TU Darmstadt, Center for Structural Materials (MPA-IW), Darmstadt, Germany; ² TU Braunschweig, Institute for Surface Technology (IOT), Braunschweig, Germany

The development of durable and efficient bipolar plates remains essential for enhancing the performance and service life of proton exchange membrane fuel cells (PEM-FC). A key design challenge is the reduction of interfacial contact resistance (ICR), which directly impacts the fuel cell's efficiency. While austenitic steel 1.4404 is widely used due to its favorable corrosion resistance and mechanical properties, its relatively high ICR limits its performance. Ferritic steel 1.4016 offers a cost-effective alternative to austenitic steel 1.4404. However, in its unmodified state, it exhibits insufficient corrosion resistance and ICR values that exceed PEM-FC target requirements set by US Department of Energy (US DOE).

This study investigates the application of low-temperature plasma nitriding to improve the surface properties of 1.4016 stainless steel. The process aims to enhance corrosion resistance and reduce ICR simultaneously by modifying the surface chemistry and morphology. The goal is to elevate the performance of 1.4016 to levels comparable with or exceeding those of 1.4404, while retaining its cost advantage.

Electrochemical corrosion tests, including potentiodynamic polarization and electrochemical impedance spectroscopy (EIS), will be conducted under simulated PEM-FC operating conditions to evaluate corrosion behavior. In parallel, interfacial contact resistance will be assessed to quantify the effects of nitriding. Preliminary tests confirm the need for surface modification, as the unmodified material fails to meet corrosion and conductivity targets. This work explores the potential of plasma nitriding as a surface engineering approach to develop high-performance ferritic bipolar plates for fuel cell applications.

Target Group | This study addresses researchers, engineers, and professionals working in the fields of fuel cell technology, surface engineering, and materials development for energy applications. It is particularly relevant for those focusing on the design and optimization of components for proton exchange membrane fuel cells (PEM-FC), including bipolar plates. The content will benefit specialists in corrosion science, surface modification, and plasma-based treatments, as well as materials scientists interested in enhancing the performance of stainless steels. In addition, the study is of interest to PhD candidates and students engaged in electrochemical testing, materials characterization, or sustainable energy technologies. Industrial stakeholders developing cost-effective, high-performance solutions for fuel cell systems may also gain valuable insights from the findings.

Covered Topics | The study explores advanced surface engineering strategies aimed at improving the performance of ferritic stainless steel for application in PEM fuel cells. It investigates the use of low-temperature plasma nitriding as a method to enhance corrosion resistance and reduce interfacial contact resistance (ICR) of 1.4016 ferritic steel. Comparative analysis with austenitic steel 1.4404 is included to assess performance improvements and cost-effectiveness. Key evaluation techniques such as potentiodynamic polarization and electrochemical impedance spectroscopy (EIS) are employed under simulated fuel cell conditions. Additionally, the study quantifies the influence of surface modification on ICR, linking changes in surface chemistry and morphology to functional performance. The results contribute to the development of durable and efficient bipolar plates that meet or exceed targets set by the US Department of Energy.

Session 407 | Functional coatings on battery powders by ALD and spray drying

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One challenge in the current status of lithium-ion battery technology is the use of cobalt-containing active materials, as these are only partially recovered from recycling processes. In this work, technological developments that avoid or greatly minimize the use of cobalt or other critical raw materials in order to contribute to sustainable technology development are presented. The main objectives of the work were to increase the energy density and cycle life of the batteries and to prevent degradation of the electrolyte. Due to the high operating voltage, undesirable side reactions occur on the surface of the cathode active materials within a battery, which reduce the available discharge capacity of the battery as the number of charge and discharge cycles increases. One approach to prevent this is to coat cathode active materials with

oxidation-stable metal oxides. The coating of the powders is intended to prevent uncontrolled decomposition reactions between electrolytes and cathode active material, thereby enabling optimized charge transfer at the interface.

In this work functional, oxidation stable coatings were applied to two different cathode materials, $\text{LiNi}_{0.5}\text{Mn}_{1.5}\text{O}_4$ (LNMO) and $\text{LiNi}_{0.8}\text{Co}_{0.1}\text{Mn}_{0.1}\text{O}_2$ (NCM811), using atomic layer deposition (ALD) and wet-chemical spray drying. Various coating materials were prepared using ALD and spray drying methods and investigated in terms of composition, coating thickness, and their electrochemical properties. Rate tests and long-term tests of thin Al_2O_3 ALD layers on LNMO indicate positive effects. For the LNMO sample coated with only 1 nm, the loss is low compared to the uncoated sample. In contrast, 5 nm Al_2O_3 already shows a considerable isolation of the material. The spray-drying tests of NCM811 with $\text{Li}_2\text{O}\cdot\text{WO}_3$ show an accumulation of tungsten on the powder surface and along the grain boundaries after the calcination. The electrochemical rate capability and cycle stability of the active material is significantly improved by coating with 0.5 mol% $\text{Li}_2\text{O}\cdot\text{WO}_3$.

Our findings demonstrate that tailored surface coatings by ALD or spray drying can effectively stabilize cathode materials, reduce undesired side reactions, and thus contribute to the development of sustainable, high-performance lithium-ion batteries.

Target Group | industry, specially small and medium enterprises

Covered Topics | energy storage

Session 408 | Reactivation of NMC cathode material from a water-based recycling process for reuse in lithium-ion batteries

Reinhard Böck¹, Claudia Schöberl², Max Braun¹, Kerstin Petrikowski¹, Surong Guo², Carlo Sibold², Seniz Sörgel¹, Holger Kaßner¹, Stephan Appel²

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The sustainability of electromobility is only possible if an efficient circular economy for battery storage is established to ensure a high level of recovery of all valuable materials from spent lithium-ion batteries (LIBs). One new approach is the development of direct recycling processes. The project's working hypothesis is that the low quality of reclaimed cathode material (recyclate) from direct recycling processes is due to delithiation and crystal structure changes in the surface area, as well as to contamination during processing. Therefore, such recyclate cannot directly replace virgin NMC cathode material. The research objective was to specifically process the recyclates previously generated from direct recycling processes using innovative process steps in order to increase the electrochemical activity of the (NMC) material to the point of being comparable to virgin material. The NMC starting material (recyclate) for processing and reactivation comes from a water-based recovery process. This primarily involves dismantling vehicle batteries on an industrial scale, largely separating the cathode and anodes, and removing the cathode material from the current collector foil using a water jet process.

The processing of the recyclate at Research Center 1 (HSE) comprised the following key process steps: 1. Debinding, 2. Hydrothermal purification, 3. Impregnation, 4. Thermal treatment, 5. Grinding and sieving. The process parameters were determined and largely optimized. The recyclates were further processed into cathodes by Research Center 2 (fem), and their electrochemical activity was investigated and evaluated in half- and full-cell tests. A recyclate performance of up to 80% (e.g., capacity of the cathodes with NMC recyclate) compared to the reference material (cathodes with new NMC material) was achieved.

The NMC recyclates were characterized after the various process steps using XRD, AAS, particle size measurements, SEM, and other methods. In contrast to previous reports [1,2], it was shown that not hydrothermal treatment, but impregnation with lithium hydroxide immediately before the annealing process enables lithiation and the associated capacity increase.

Additional monitoring of the process steps served as an initial life cycle assessment (LCA), with the aim of determining energy and chemical consumption and comparing different methods and process parameters. The recycled material processing carried out does not require complex industrial infrastructure and is therefore feasible for SMEs in the recycling, raw material, and battery production sectors, making it very interesting from an economic perspective.

[1] Shi, Y., Chen, G., Liu, F., Yue, X., & Chen, Z. (2018). Resolving the compositional and structural defects of degraded $\text{LiNi}_x\text{Co}_y\text{Mn}_z\text{O}_2$ particles to directly regenerate high-performance lithium-ion battery cathodes. *ACS Energy Letters*, 3(7), 1683-1692.

[2] Davis, K., & Demopoulos, G. P. (2024). Effective upcycling of NMC 111 to NMC 622 cathodes by hydrothermal relithiation and Ni-enriching annealing. *Next Energy*, 4, 100122.

Target Group | Battery recycling companies, battery manufacturers, fine chemical traders, process equipment manufacturers

Covered Topics | Direct recycling, NMC batteries, recycling of lithium-ion batteries, processing of black mass (NMC), processing of NMC recyclates, sustainable battery disposal

October 16, 2025

Keynotes

KN-0301 | Plasma Technologies for Applications in Chemical and Environmental Engineering

Tim Nitsche

Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT, Chemical energy storage, Oberhausen, Germany

Plasma technologies have already proven to be widely established in solid material processing, particularly in applications such as plasma etching, surface modification and thermal processes like welding. However, there are also promising technologies in the field of chemical gas conversion and gas cleaning. Several plasma-based technologies have been already developed for various applications and some could be already utilized for the industrial scale (e.g. electrostatic filter, Birkeland-Eyde Process, Hüls Process). However, most of them have not been widely applied in the industry so far since the electricity was mainly generated from fossil resources and thus alternative processes, which could also enable the chemical conversion with direct utilization of these fossil resources, were in general more energy efficient and thus more economically.

In light of the current energy transition, an efficient and direct usage of electricity is becoming increasingly necessary. In this context, plasma technologies especially with non-thermal characteristics offer great potential, which will be highlighted in this talk. Selected applications from environmental and chemical engineering that are already implemented on an industrial scale will be presented, along with promising future applications that have the potential to revolutionize the industry. By discussing these technologies, it will become evident how plasma technologies can contribute to reducing CO₂ emissions and improving resource utilization, thereby playing a key role in sustainable development. The lecture aims to raise awareness of the benefits and challenges of these technologies and to underscore their significance in the context of modern industry.

KN-0302 | Plasma-Driven Methane Conversion for low-carbon Hydrogen and Carbon Utilization

Jens Hanke

Graforce GmbH, Berlin, Germany

While plasma technologies have long been established in surface engineering and material processing, their full potential for chemical gas conversion has only recently begun to unfold on an industrial scale. One of the most promising developments in this field is the application of high-temperature methane plasmalysis to produce CO₂-free hydrogen and solid carbon.

Graforce has pioneered this approach by transferring various plasma principles into robust, continuous processes capable of converting methane or flare gas at industrial scale with a 98 % conversion rate into hydrogen and solid carbon. The process operates at ~1,500 °C under near-ambient pressure, splitting methane without generating CO₂. Powered by renewable electricity, the technology achieves hydrogen production costs in the range of €1–2.5 per kg and delivers solid carbon as a valuable industrial feedstock, replacing carbon-intensive materials such as petroleum coke in pigment production, metallurgy, and construction.

In Austria, a refinery-integrated system with a capacity of 1,200 kg H₂/day was built and commissioned to supply low-carbon hydrogen to a hydrogen-powered CHP plant, generating clean electricity and heat for 800 households. The solid carbon is applied for soil enhancement, ensuring its long-term sequestration in the ground.

This presentation will highlight the pathway from laboratory research to industrial deployment, focusing on:

- process design and scale-up challenges,
- integration into existing industrial operations,

- market applications for hydrogen and carbon products,
- and the role of methane plasmalysis in global decarbonization strategies.

By bridging advanced plasma physics with commercially viable process engineering, methane plasmalysis demonstrates how plasma technologies can move beyond niche applications to become a central pillar of the low-carbon economy.

October 16, 2025

»Power-2-Chemicals«

P2C01 | Electric Power to Molecules: The Role of Low-Temperature Plasmas in Sustainable Gas Conversion

Peter Awakowicz, Thomas Mussenbrock

Ruhr University Bochum, Chair of Applied Electrodynamics and Plasma Technology, Bochum, Germany

Electrification is becoming a central strategy in sustainable industrial transformation. In this context, plasma-chemical gas conversion has gained significant momentum as a promising technology for both environmental remediation and the synthesis of valuable chemical products. Applications range from the removal of trace substances in the ppm range from large volume gas streams to the conversion of waste gases into intermediate or end products with concentrations in the percentage range. Surface Dielectric Barrier Discharges (SDBDs) have emerged as particularly suitable plasma sources for these tasks. They operate at atmospheric and elevated pressures, generate energetic electrons while maintaining low gas temperatures, and offer high robustness and ease of integration into modular reactor systems.

A key challenge in the practical application of such plasma systems is the need for process-specific adaptation and optimization. Achieving a competitive specific energy input per converted molecule requires more than simply operating a suitable plasma. It demands detailed and quantitative characterization. This presentation addresses this challenge by combining a broad experimental approach with advanced diagnostics and modeling techniques. Electrical and optical diagnostic methods are employed to determine fundamental plasma parameters and electrical characteristics. Complementary simulations, including those of plasma filaments and their interaction with gas flows, are used to deepen the physical understanding of the system and its behavior under operating conditions.

Flow visualization techniques, such as Schlieren imaging and laser stroboscopy, partly conducted in wind tunnel environments, provide valuable insights into gas dynamics. The strong agreement between experimental observations and numerical models supports the development of predictive tools for reactor design. By coupling plasma diagnostics, flow dynamics, and plasma-chemical modeling, this work lays a robust foundation for the targeted improvement and optimization of gas conversion processes. Ultimately, these insights contribute to a broader vision: using electric power to drive clean, efficient, and scalable chemical transformations in future energy and materials systems.

P2C02 | Plasma-Assisted Municipal Waste Treatment: A Scalable Solution for Decentralized Waste Management

Shahed Abbasisooha

Ermafa environmental technology, Vienna, Austria

The global challenge of municipal solid waste (MSW) is intensifying, with annual production expected to surge from 2.01 billion tons today to 3.40 billion tons by 2050. Despite growing awareness, current waste management systems remain largely unsustainable. A relatively small fraction of waste, less than 20% diverted through recycling or composting, while the majority is inadequately handled: substantial portions are landfilled, openly dumped, or incinerated. These practices pose severe environmental and health risks. Landfilling, although economically convenient, releases harmful contaminants into air and water, including greenhouse gases like methane and carbon dioxide, as well as toxic leachate containing hundreds of hazardous chemicals. Incineration, while reducing waste volume and enabling energy recovery, is energy-intensive and produces hazardous ash residues that require complex and often risky disposal methods.

Thermal processing of solid waste aims to convert waste into gaseous, liquid, and solid products, often with energy recovery. Key objectives include the destruction of organic and hazardous components, volume reduction, the generation of inert products, and significant energy valorization. In this context, thermal plasma technology (TPT) emerges as a highly promising solution. TPT efficiently gasifies the organic content of solid wastes into syngas, suitable for heat and power generation, while simultaneously vitrifying inorganic materials into a stable, glassy slag with very low leachability. This process facilitates near-zero emissions and maximizes resource utilization.

The primary goal of this work is to introduce a plasma-assisted waste treatment system optimized to maximize energy production through the generation of high-quality syngas, and to achieve a substantial reduction in waste volume, converting diverse waste streams into inert ash and non-combustible materials. This system is engineered to accommodate waste streams with high moisture content, up to 30%, and is anticipated to achieve a cold gas efficiency exceeding 80% under optimal operating conditions, along with a tar content of less than 10 mg/Nm³ in the produced syngas. Our research highlights TPT's significant potential as a scalable, resilient, and sustainable solution for decentralized waste management, directly contributing to a circular economy by transforming waste into valuable resources.

October 14-15, 2025

Poster Exhibition

S1-1 | Surface wettability modification of polymers for use in electrocaloric heat pumps

Maria Barrera¹, Daniel Pinkal², Michael Wegener², Cordula Vogel³, Fred Fietzke¹

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Thanks to their remarkable electrocaloric response and mechanical flexibility, relaxor ferroelectric terpolymers are becoming increasingly popular in the design of electrocaloric heating and cooling devices. In this case, the electrocaloric system relies on latent heat transfer, facilitated by fluid condensation and evaporation at the polymer surface. However, the intrinsic hydrophobic (water-repellent) surface of the terpolymers remains a challenge for this purpose. This research ^[1] explores methods to enhance the wettability of flexible polyimide films, which are used to encapsulate the terpolymers and improve thermal exchange.

The polyimide surfaces were modified through a dual approach: plasma etching followed by the deposition of metal oxide thin films using pulsed magnetron sputtering. To achieve optimal wetting behavior, various sputtering parameters — including pulse length, gas mixture, and exposure duration — were systematically adjusted. The treated surfaces were then examined for changes in chemical composition and physical structure, with wettability assessed at macro-, micro-, and nanoscale.

Once the desired wetting characteristics were attained, the surface-modified polyimide foils were used as encapsulation layers for electrocaloric terpolymer components. This work also explores the impact of this encapsulation strategy on the electrocaloric response, providing insights into the relationship between surface engineering and functional device performance.

The findings of this work support the development of more effective electrocaloric heat pumps, advancing sustainable and energy-efficient solid-state heat transfer technologies.

^[1] Maria Barrera, Daniel Pinkal, Michael Wegener, Cordula Vogel, Fred Fietzke. Surface wettability modification of polymers for use in electrocaloric heat pumps. *Surface and Coatings Technology* 505 (2025), 132080.

S4-1 | You don't get anything from predictions, until you use them - About the use of digital methods to optimize and control your coating processes

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After a long day in the office, thinking about optimizing your coating process, you step in your car, hit the button on Google Maps "Home", and it predicts the best way for you to drive to your home destination.

You are at home, thinking about a nice gift for your friend, you go to Amazon and after you put in some searches, Amazon suggests the gift you never had thought of.

And the next day, you sit in your office and thinking about optimizing your coating process, and nothing gives you a guideline.

These days, digital twins of your coater are able to give you an accurate prediction of what you want to achieve with your coating. Similar to the prediction of an optimal route through a traffic jam or the optimal gift for your friend, theoretical and – as an extension – modern data-driven (ML, AI) methods have the same abilities.

However, the reason why they are not used all the time is because they are not used all the time. Think about the prediction of Google Maps, it is so widely used, that their data basis is vast, so their predictions are accurate. The same goes with Amazon and your accurate gift for a friend.

So, every time you think in regard of simulation for coating purposes: "Yes, simulation is nice, but it does not give me the predictions I want". Think about yourself and how much did you to help simulations for coatings come forward.

We encourage you, to take data from your processes, to simulate your processes, to be open to theoretical prediction for you processes. You are the source to make the development of a new coating process as easy as to navigate yourself through a huge traffic jam on the route to your destination.

As an example, we present initial work of using machine learning methods to extract and identify stable coating process parameters. As a first stage, these learned patterns will targeting non-ideal machine states as e.g., leakage of the coater. The model – together with the gained experience in how-to prepare coating data for efficient learning – will be extended sequentially by adding more and more recorded and measured data (e.g. layer properties) and even by synthetic, i.e., simulated data.

Since running ML-models is fast – compared to running pure classical simulations – models of these kind will allow “faster-than-real-time” predictions of the coating and the coater state based on real-time data and therefore are suitable for in-situ process control.

P01 | Three-dimensional Analysis of Plasma Properties for Industrial HiPIMS/dcMS Batch Processes

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RWTH Aachen University, Surface Engineering Institute, Aachen, Germany

Plasma-based PVD processes such as High Power Impulse Magnetron Sputtering (HiPIMS) are used to produce wear and friction reducing hard coatings, which enable the efficient coating of intricate 3D geometries at high temperatures. In industrial PVD batch processes, a multitude of factors influence the coating plasma and thus the deposited coatings. Understanding plasma parameters and the impact of process parameters on these plasma characteristics is crucial for enhancing efficiency in industrial development processes.

Aim of the project is to establish time- and spatially-resolved plasma diagnostics using optical emission spectroscopy (OES), which can also be applied under industrial conditions. A newly developed, temperature and rotationally stable integration into the system enables time-resolved OES with a resolution of $\Delta t = 5 \mu s$ to be realized for the first time, specifically qualified for HiPIMS processes. The monitoring will be tested across various coating processes with different process parameters, target compositions, and elevated process temperatures $T > 400 \text{ }^\circ\text{C}$. By correlating OES data with results from a peak value analyzer, a comprehensive database is created to directly link plasma properties with process and coating characteristics.

This setup allows instabilities to be detected at an early stage, enabling targeted control over processes and helping to avoid faulty batches. The knowledge gained helps significantly improve coating quality, process stability, and resource efficiency – especially concerning the needs of small and medium-sized enterprises (SMEs) involved in both contract coating services and the development of plasma diagnostics.

P02 | Effect of superimposed HiPIMS + RF on HiPIMS Current

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High-quality, defect-free compound coatings are required for many applications, including e.g. solar adsorbers and barrier coatings for hydrogen applications. However, their technical realization within an economic deposition process is still a great challenge. We therefore investigated a superposition of RF and HiPIMS power on a single magnetron and studied the influence of target voltage and reactive gas flow on process stability and peak currents for the reactive deposition of ZrY, Titanium, Aluminium, as well as their corresponding nitrides and oxides. For that purpose, we modified a custom-built sputter coater (FHR SV 400) and connected a SPIK3000A-EF-05 HiPIMS Generator (Melec) and a CEASAR 1325 RF Generator (Advanced Energy) to the same source. The outputs of both power supplies were continuously superimposed. In non-reactive mode, the applied RF reduced the HiPIMS peak current for Al and Zr. When nitrogen or oxygen was added during aluminium deposition, the HiPIMS peak current in the superimposed HiPIMS+RF case exceeded that of HiPIMS-only. The same trend was seen for reactive deposition of ZrYOx, but not for ZrYNx. For titanium, in contrast, superimposed HiPIMS+RF decreased the peak current in both non-reactive and reactive (TiNx, TiOx) processes relative to HiPIMS-only.

A plausible explanation is the material-dependent secondary-electron emission yield (SEE) of the target and its reactive surface compounds. SEE in DC discharges has been systematically reported for many materials (e.g., Depla et al., 2009). For aluminium, reactive operation yields a higher secondary-electron yield than non-reactive sputtering, whereas titanium shows a lower reactive SEE than its metallic state. While DC excitation is driven predominantly by secondary electrons emitted from the cathode surface, RF sustains charge carriers via electron oscillations in the plasma bulk. In addition, the RF-induced dark space near the target depletes electrons in the vicinity of the surface. Together, these effects can account for the observations: when the reactive surface exhibits high SEE (e.g., Al in O_2/N_2 , $ZrYOx$), RF-assisted pre-ionization can overcome near-surface depletion and raise the HiPIMS peak current. When the reactive surface has low SEE (e.g., Ti in O_2/N_2 , $ZrYNx$), the avalanche formation is suppressed, leading to a reduced HiPIMS peak current under HiPIMS+RF.

P03 | Influence of power delivery modes on the sputter deposition of Zinc Tin Oxide films from compound targets

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Zinc Tin Oxide (ZTO) thin films are transparent conductive oxide coatings that, contrary to e.g. Indium Gallium Zinc Oxide (IGZO) or Indium Tin Oxide (ITO), do not rely on the inclusion of scarce and thus expensive raw materials. Due to the transparency to visible light yet still being electrically conductive, prospect applications of ZTO are in thin film electronics such as thin film transistors or windshield defrosting. In this work, we utilized two rotary compound ZTO targets in an industrially sized box coater to deposit films of approx. 150 nm thickness. While these two targets can be powered alternately by a rectangularly shaped voltage between the targets, we also compare this traditional bipolar sputtering to the Dual Reverse Pulsing mode (DRP®), where both targets are simultaneously pulsed against a shared floating anode. The optical properties are examined by spectroscopic ellipsometry, and we find that only a small amount of oxygen in the sputtering gas is sufficient to yield low absorption in the visible wavelength range. Yet, the optical transparency and electrical resistivity can still be universally tuned by changing the sputtering gas conditions, irrespective of the chosen power delivery mode. However, coatings with similar film properties can be deposited faster and with a reduced heat load to the substrate in DRP mode compared to the traditional symmetric bipolar pulsing.

S1-2 | Enhancing the Crystallization of Sputtered Titanium-Oxide-Films for Antipathogenic Surface Applications via Various Annealing Techniques

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Annually, approximately 4 million people in Europe acquire healthcare-associated infections (HAIs). To mitigate the spread of pathogens, a photocatalytic coating with superacidic surface properties has been developed, offering dual action through the generation of surface protons and reactive oxygen species. This antipathogenic coating is composed solely of benign materials and does not include compounds that could induce antibiotic resistance. The antipathogenic effect of the films is achieved by acidifying the surface of crystalline titania thin films through a reactive gas-phase photo-fixation process, which results in the formation of strongly surface-bound sulfate groups, while preserving the photocatalytic properties of the film.

The titania films were deposited on glass and polymer substrates using a sputtering process from a dual magnetron with ceramic titanium dioxide targets. Various process parameters, including deposition temperature and oxygen flow, were adjusted during the process. This examines the effect of process parameters on titania film crystallization subjected to different post-annealing methods. A focus was put on analyzing the dependence of film crystallinity and structure on annealing method. Among the crystallization methods, both furnace annealing and the ultra-fast technique of Flash Lamp Annealing (FLA) were investigated. The crystallization of the films was characterized using X-ray Diffraction (XRD). It is shown that FLA leads to crystalline titania films in the anatase phase. Additionally, it was found that elevated

temperatures during deposition result in faster crystallization in the furnace annealing. Another observation is that the crystallization methods have differing effects on the anatase crystal structure. This finding is significant as photocatalytic activity is closely related to the crystal structure. A higher anatase (004)/(101) diffraction peak intensity ratio was achieved through FLA compared to furnace annealing. It is known that the relative intensity of the (004) peak correlates with photocatalytic activity of anatase. Moreover, we have previously shown that the sulfate bonding is stronger on anatase (004) planes. Consequently, we show that FLA annealing of titania films prepared by dual magnetron sputtering facilitates synthesis of super-acidic sulfated titania surfaces. Furthermore, it was demonstrated for the first time that sulfur attachment is possible using a reactive FLA process.

P13 | Inverted Fireballs for Advanced Manufacturing

Gerhard T. Eichenhofer¹, Johannes Gruenwald^{2,3}, Jacob Reynvaan³, Martin Fenker⁴, Holger Kassner⁴

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Inverted Fireballs (IFBs), first discovered in 2011^{1,2}, represent a promising, not yet fully explored phenomenon in low-pressure plasma physics. While IFBs have so far been recognized primarily as a topic for fundamental research, recent experiments aim to transition this technology into industrially viable plasma processing systems. The objective is to use IFB technology for advanced applications such as plasma and vacuum coating (PVD, PE-CVD, ALD), cleaning, nitriding, and etching. Current efforts focus on validating and expanding the foundational understanding of IFBs, with the goal of developing a plasma system that achieves up to 10 times higher plasma density³ while reducing energy consumption by at least 30%. Industry-oriented prototypes have already demonstrated successful applications, including the production of ultra-smooth graphite surfaces potentially paving the way for innovations in materials like graphene and other highly functional carbon forms. Applied research has confirmed several key characteristics of IFBs, such as high-density plasma within a precisely defined volume (inside a gridded anode), exceptional plasma homogeneity⁴ due to a uniform plasma potential within the IFB region, and a superior efficiency in sustaining plasma with minimal energy input.

Beyond improving the process quality, IFB-based systems are expected to extend maintenance intervals of industrial equipment by a factor of four. This poster presents an overview of IFB surface treatments, recent experimental results, and an outlook for its integration into next-generation plasma processing technologies.

References:

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⁴Gruenwald, J., et al. "Inverted fireball deposition of carbon films with extremely low surface roughness." *Carbon Letters* 33.1 (2023): 225-231.

P14 | Development of Electrochemical Characterization Methods for Metallic Bipolar Plates in Fuel Cell Applications

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Bipolar plates are a key component in proton exchange membrane fuel cells (PEM-FC), playing a crucial role in both performance and durability. A trend is emerging from graphite towards metallic materials such as austenitic steel 1.4404 (AISI 316L), primarily due to significant potential for volume reduction as well as improved mechanical stability and gas tightness. This particular steel is known for its excellent corrosion resistance, attributed to the passive chromium oxide layer formed by its high chromium content. However, this same layer contributes to a relatively high interfacial contact resistance (ICR), limiting its effectiveness as a bipolar plate material. While various strategies exist to

reduce ICR, they must be carefully balanced to avoid compromising corrosion resistance, especially under the chemically aggressive conditions during operation.

This study aims to experimentally investigate the electrochemical stability and electrical contact resistance behavior of various surface modifications applied to 316L, with reference to the U.S. Department of Energy (DOE) technical targets for bipolar plates. The untreated base material serves as a reference for comparative analysis. Two central research questions are addressed in this study:

- (1) To what extent can the DOE-recommended test protocols be optimized?
- (2) How do selected surface treatments influence corrosion resistance and ICR?

Dedicated test setups were developed to conduct electrochemical measurements (potentiostatic, potentiodynamic and electrochemical impedance spectroscopy) and ICR testing, in accordance with DOE specifications. The first phase focused on evaluating the recommended test procedures, identifying potential time savings and methodological optimizations. Preliminary results indicate that the open circuit potential (OCP) delay time can be reduced from 3600 s (DIN EN ISO 17475) to 900 s without significantly affecting the current response. Furthermore, argon purging was found to have minimal impact on measurement reproducibility, indicating that reliable results can also be obtained without purging, thereby reducing testing complexity and costs.

P04 | Inverted Fireball-Assisted Magnetron Sputtering: A Novel Approach to Thin Film Deposition

Martin Fenker¹, Gerhard T. Eichenhofer², David Baeurer^{1,4}, Johannes Gruenwald³, Moritz Oberberg⁵, Joachim Albrecht⁴, Holger Kaßner¹

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Plasma fireballs (FBs) and their less studied variants, inverted fireballs (IFBs), are fascinating phenomena within low-temperature plasma physics that are attracting increasing interest due to their potential for applications in surface treatment. While FBs are characterized by luminous, spherical plasma formations, IFBs have a spatial structure that is determined by the shape of the anode grid.

This poster presents the first successful ignition and application of an inverted fireball using a magnetron sputtering source. By applying a positive bias to custom-fabricated gridded cylindrical electrode, we achieved stable IFB generation in a PVD environment. Process parameters, including substrate bias, the anode configuration and plasma composition (reactive, non-reactive), were varied.

The IFB-assisted sputtering process was used to deposit titanium thin films onto high-speed steel substrates. Comparative results demonstrate a clear enhancement in film hardness when the IFB was active. Plasma diagnostics, including multipole resonance probing in Ar/O₂ atmospheres and optical emission spectroscopy, revealed elevated plasma densities ($\sim 10^{16} \text{ m}^{-3}$) and significant electron temperatures, even at a long distance from the magnetron source.

Our findings highlight the potential of IFBs as controllable plasma structures for modifying deposition characteristics, offering a new avenue for tuning film properties in advanced coating technologies.

P15 | Understanding the effect of ignition voltage in the dynamic pulse-current control mode of HIPIMS discharge

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This study investigates the benefits of constant-current operation in High Power Impulse Magnetron Sputtering (HIPIMS) and its influence on plasma stability, ionization efficiency, and thin-film quality. Maintaining a stable current ensures precise energy control, enabling uniform, repeatable deposition and suppression of self-sputtering effects, particularly in copper plasmas. Real-time voltage regulation adapts to rapid plasma impedance fluctuations, preventing overshoot and arcing while supporting longer pulse durations and higher deposition rates. The

analysis highlights three distinct phases of the voltage waveform and examines the critical role of ignition voltage in plasma initiation and stability. Optimizing ignition voltage improves sputtering yields yet avoids discharge instability, emphasizing the need for material- and process-specific control strategies. These findings advance HIPIMS process optimization, enabling high-quality coatings and enhanced material properties across diverse applications.

P16 | Influence of different discharge frequencies on gliding discharge ammonia decomposition for hydrogen recovery

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Ammonia is a promising hydrogen storage medium due to the ease of condense, and availability of existing infrastructure. Withing circular carbon technologies ammonia can serve as a carbon-free hydrogen carrier, enabling storage and transport of green hydrogen produced from renewable sources. It's decomposition results only in H₂ and N₂ products, without any other harmful compounds. Recovered hydrogen can then be used for power generation, as a fuel and support for closed-loop processes. When ammonia is synthesized from green hydrogen and atmospheric nitrogen, the system forms a reversible, low-emission cycle. However, the effective use of ammonia depends on the development of efficient, scalable, and low-temperature decomposition methods.

In this work the decomposition of ammonia was investigated in an atmospheric pressure gliding arc plasma. The experiments were conducted under conventional approach of low-frequency discharge of 50 Hz and high frequency of 20 kHz, 30 kHz, and 50 kHz using an industrial scale TruPlasma Bipolar HV power supply.

High conversion was achieved for processes performed at high frequency of kHz range with Bipolar HV power supply. Furthermore, after optimizing the power supply settings and matching it to the gliding discharge reactor it was possible to achieve NH₃ conversion of approx. 55% without the use of catalyst at a discharge power of 400 W.

P05 | New generation of ARC power supplies for future applications and upgrade of legacy systems

[Wojciech Gajewski](#), Maciej Obiała, Daria Mikulska, Bartosz Szpondowski, Mariusz Koziarowicz

TRUMPF Huettinger Sp. z o.o., Zielonka, Poland

Industrial arc-PVD is expanding across tooling, tribology, and decorative sectors, but legacy supplies constrain ion-energy control, macroparticle suppression, and factory integration. We introduce the TruPlasma ARC Series, a next-generation modular power platform with embedded, dual-level pulsing to tailor ion-assisted growth and curb macroparticles without external hardware. A compact, high-power-density design independently drives up to three cathodes, delivering the smallest footprint in its class and enabling multi-cathode recipes. Industry-4.0-ready connectivity provides closed-loop control and diagnostics, while full mechanical and electrical compatibility enables retrofits with minimal downtime. High-efficiency conversion and closed-loop water cooling reduce wall-plug energy improving sustainability and thermal stability. We will report pulsing modes, power-stability metrics and integration workflows with benchmarks linking electrical efficiency, arc stability and macroparticle incidence to coating performance.

S1-3 | Effect of Mo and W over the crystallinity and mechanical properties of magnetron sputtered AlTi(MoW)N layers

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AlTiN is widely used as protective coating material for cutting and forming tools due to its high hardness, wear and oxidation resistance even at high temperature (up to 800 °C) and its moderate friction coefficient. In this study, the effect of the addition of Mo and W in the microstructure of magnetron sputtered AlTiN coating has been evaluated in terms of their microstructure, lattice and hardness, as a function of the resulting compositions and growth conditions. The coatings have been deposited on high-speed steels AISI-M2 (60 HRC) by co-sputtering a Al₃₃Ti₆₇ target (700x100 mm LW) in DC_pulsed mode and a Mo or a dual-tile Mo/W target (same sizes) in HIPIMS mode, thus obtaining TiAlMoN and TiAlMoWN coatings respectively. The coating series presented in this study were prepared for different HIPIMS sputtering power over the Mo – Mo/W targets, while keeping constant the DC sputtering power over the AlTi target. In addition, the influence of the N₂ mass flow has also been investigated.

The effect of the Mo and Mo/W co-sputtering affects significantly the structure and hardness of the coatings. The dominant face-center-cubic (FCC) lattice structure of the Mo-free AlTiN losses crystalline order as the Mo and the Mo/W sputtering powers increase. On the other hand, the indentation hardness of the coatings notably increases as the Mo content increases into the AlTiN lattice structure. In addition, the sputtering of dual-tile Mo/W target leads to even higher hardnesses over these of the TiAlMoN coatings for the same sputtering conditions.

The N₂ mass flow has also notable effects on the crystallinity and hardness properties of the coatings. With high N₂ flow rates, the XRD analyses show highly crystalline FCC nitride lattices with a strong preferred substrate-parallel orientation of the (111) planes, and low hardnesses. Reducing the N₂ flow rates leads to a XRD peak amorphization and an increase of their indentation hardnesses. The research study is completed with the evaluation of mapping nano-indentation tests, aimed to extract hardness and elastic modulus maps across sample surface, thereby revealing local variations in mechanical response and allowing comparison between the different coatings and setting fingerprint principles.

It will be discussed whether the Mo and W containing AlTiN based coatings could be qualified as medium/high-entropy nitrides as the dominant phase is a solid solution cation sub-lattice of 4 metals. In this frame, the research carried out is part of the Horizon Europe project M2DESCO (grant agreement 101138397), aimed to develop novel computational models for the design of safe & sustainable high-entropy coatings.

S1-4 | Improved coating properties by additional plasma source during sputter process

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Sputtering processes have been used for many decades to deposit coatings for a wide range of applications. For wear protection applications, HiPIMS is often used because it can produce smooth and dense coatings. However, the drawback is the low deposition rate. By generating an additional highly ionized plasma at the substrate, it is possible to create smooth and dense layers with improved deposition rates. It is demonstrated that the properties of typical hard coatings such as TiN or TiAlN improve due to changes in the layer structure. Additionally, the process window is expanded.

S3-1 | Development and application of low energy plasma treatments for steel surfaces

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Plasma cleaning can be an efficient way of preparing metallic surfaces for subsequent coating procedures by removing oxides and other contaminants and consequently enhancing the adhesion of deposited coating layers [1]. A versatile low-pressure, pulsed-DC plasma treatment unit designed for steel batch samples is developed and investigated. The plasma treatment is characterized via retarding field energy analyzer measurements, revealing ion flux densities up to $J_i = 7 \text{ A/m}^2$. By mapping the ion flux density on the sample surface, a spatial distribution consistent with the anode tube geometry. Contact angle measurements of plasma treated steel surfaces show an increase in surface free energy following short plasma treatment at an energy density of approximately $E_A \approx 5 \text{ J/cm}^2$. X-ray photoelectron spectroscopy confirms a reduction of carbon compounds and oxides on plasma treated surfaces. These findings demonstrate the potential of the plasma treatment as a pre-treatment in industrial applications requiring clean, reactive metal surfaces, such as physical or chemical vapor deposition processes.

[1] H. C. Barshilia et al, 2012, *Vacuum* 86 1165–1173

S4-2 | Laser Ultrasound - A Non-Contact and Non-Destructive Methodology for Ultra-Thin and Thin Film Metrology

Mike Hettich, Felix Noll

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RECENTD develops novel methods for the characterization of thin film systems. Non-destructive testing of thin and ultra-thin films down to a few nanometer thickness is possible with laser-based ultrasound. Due to the all-optical excitation and detection of high-frequency acoustic waves and pulses no mechanical contact is required and makes it an promising asset applicable during thin film growth. Because acoustic waves are used to probe the films, Laser Ultrasound can also test films as well as micro- and nanostructures that pose a challenge to optical techniques in case of opaque materials. Subsurface information can be retrieved and combined with spatial scanning to provide tomographic images of the device of interest, e.g. to check film homogeneity. A wide range of film systems - including film stacks, multilayers, superlattices, freestanding films, and single layers - can be analyzed.

Apart from structural and elastic characteristics, e.g. film thickness, subsurface structures and defects and sound velocities with respective elastic moduli, information about adhesion and delamination can be inferred. In the case of optically transparent or semi-transparent films it is also possible to measure simultaneously the depth-resolved sound velocity, i.e. elastic characteristics, in combination with the index of refraction which also gives access to doping profiles. Typical axial resolution of this specific approach are in the range of 10s of nanometers while the typical lateral resolution is typically on the order of several hundred nanometers to micrometers. We will demonstrate the capabilities of this method on different thin film systems and nano-/microstructures.

P17 | Roll-to-roll magnetron sputtering of alumina (Al_2O_3) onto plastic films for sustainable packaging

Michael Hoffmann, Manuela Ehrhardt, Cindy Steiner, Matthias Fahland

Fraunhofer Institute for Electron Beam and Plasma Technology FEP, Dresden, Germany

The use of mono-materials is one important factor for increasing the recycling quote of plastics packaging. In case that a primary plastic film does not provide a sufficient permeation barrier against gases like water vapor and oxygen, functional barrier layers are required that do not compromise a recycling process. We investigated thin transparent alumina (Al_2O_3) layers in the 10 nm thickness range as an option for such barrier layers on PET or polypropylene films. These layers are produced by reactive magnetron sputtering in a 330 mm pilot production scale roll coater. Potential applications are primarily in medical packaging.

Process control for reactive magnetron sputtering is challenging, in particular for alumina. We show options for a stable process using a system with a single rotatable aluminum target and a rod anode by employing optical plasma emission spectroscopy for feedback control. We investigate conventional pulsed mode at frequency of 50 kHz and duty cycle of 80% as well as a HiPIMS (high power impulse magnetron sputtering) generator at frequency of 1kHz and duty cycle of 10%. Feedback control is provided by using the intensity ratio of aluminum and argon plasma emission lines to control the flow of the reactive gas (oxygen) into the deposition chamber.

For both pulse modes, we see the characteristic hysteresis behavior between metallic and oxidic deposition mode. We show how the process can be ramped up towards stable operation in the transition regime. There, we obtain dynamic deposition rates of e.g. 10 nm m/min for transparent layers of 20 nm thickness on commercial PET or polypropylene substrates. The water vapor transmission rate (WVTR) of these layers is in the range of 0.1 g/m²/day (at 38°C, 90% r.H.). We proved the reproducibility of the process.

Our studies show the route towards an industrially feasible roll-to-roll process of producing very thin transparent alumina-based permeation barrier layers on plastic films which will not hinder recycling processes. This work was supported by the Fraunhofer Internal Programs under Grant No. PREPARE 40-00382.

S4-3 | Near-process Sensor Integration for Characterization of in-vacuo Deposited Thin Films by Eddy-Current Sensor Metrology

Michael Hofmann, Marcus Klein
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Process control and monitoring strategies in industrial manufacturing rely on the information generated by a variety of physical sensor techniques. One such metrology is based on eddy current technology, which enables non-contact, high-speed measurement with well-proven reliability. Parameters such as sheet resistance, resistivity, layer thickness, anisotropy etc. provide valuable insight for thin film coatings. Instantaneous data and statistical analysis of the process behavior is often desired in vacuum conditions to increase the through-put and machine uptime, and hence utilizing cost-sensitive resources wisely already at the very early wafer manufacturing stages.

However, it can be challenging for vacuum coating line developers and process engineers to select technologies for near-process integration. On one hand that's due to the limited space for mounting in-vacuo setups and the required compatibility for high-vacuum conditions. On the other hand, the commonly applied layer deposition methods and layer treatment steps involve surfaces of high temperature affecting the sensor hardware or stability in a negative way.

In this context the poster explores the capabilities of non-contact, non-destructive eddy current metrology for material characterization in challenging environments. The poster suggests solutions for finding the most cost- and performance-effective measurement setups for R2R inline web coatings and vacuum cluster tools for wafer metallization. Most suitable positions associated with the vacuum handling workflow have been identified which provide a clever way for either retro-fitting existing cluster tools at the interconnection position in between transfer and deposition chambers, or alternatively attaching a dedicated metrology chamber module (MCM).

P18 | Endless SiC-Fiber Coatings for Usage in Ceramic Matrix Composites

Mario Krug, Katrin Schönfeld, Mandy Höhn, Clemens Steinborn
Fraunhofer IKTS, Dresden, Germany

Hot gas-stable, high-temperature-resistant materials with high damage tolerance are required, particularly in the field of turbine applications (e.g., aircraft turbines). Ceramic matrix composites (CMCs) are particularly well suited for this purpose, combining the high-temperature resistance and hot gas stability of a ceramic (e.g., SiC) with the required damage tolerance through suitable fiber reinforcement (e.g., SiC continuous fibers). Within the poster a R&D-tool is described capable to deposit two different coatings at the same time in a roll-to-roll process using thermal CVD (chemical vapor deposition). A sample of SiC-CMC is shown where SiC endless fiber material was used as reinforcement material coated with BN and sequentially with SiC.

S3-2 | Resource-Efficient Plasma Nitriding of Stainless Steels for Combined Tribological and Corrosive Stresses

Hanno Paschke¹, Huang_Minh Vu², Peter Kaestner¹, Holger Hoche², Matthias Oechsner², Guenter Braeuer¹

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Low-temperature plasma nitriding of austenitic stainless steels increases wear resistance through the formation of the so-called S-phase. Unfortunately, the thickness of this wear-resistant phase and the corrosion behavior are inversely proportional to the process parameters and the material and material condition, for example, cold-forming-induced martensite.

The aim of the project RePlaNiro is therefore to determine process parameters for the plasma nitriding treatment of austenitic steels that are individually tailored to the respective material and its condition. This enables the nitriding results to be predicted as a function of the above-mentioned factors. This is illustrated on the poster for the nitriding depth in solution-annealed austenitic steel 1.4307.

Within the project RePlaNiro, the model is extended to include the factors of microstructure and surface properties. In addition, the corrosion behavior is investigated. This enables SMEs to achieve reproducible plasma nitriding processes.

S1-5 | Self-lubricating TiBN coatings using pulsed arc PVD technology to reduce friction and wear

Marta M. Marti, Max P. Möbius, Kirsten Bobzin

RWTH Aachen University, Surface Engineering Institute (IOT), Aachen, Germany

Self-lubricating coatings based on layered crystal structures, such as diamond-like carbon (DLC), or molybdenum disulfide (MoS₂), have significant potential to reduce friction and wear. However, these coatings are limited at temperatures above $T \geq 400$ °C due to their oxidation resistance. A promising solution is the integration of the solid lubricant hexagonal boron nitride (h-BN) into hard coatings, as h-BN is oxidation-resistant up to a temperature of approximately $T \approx 900$ °C. The goal of this research project is the development of self-lubricating TiBN hard coatings to significantly improve the wear and friction properties of tools used at high temperatures. By reducing friction and wear on tools in applications such as hot forming and machining of non-ferrous metals like titanium and aluminum, process costs are expected to be lowered and sustainability improved.

S1-6 | DLC-Coatings for PFAs-free lubricants

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Per- and polyfluorinated alkyl substances (PFAS) are characterized by high thermal and chemical resistance but pose a significant environmental concern. The experiments aim to investigate sustainable alternatives to PFAS-containing lubricants for mechanical systems with focus on a combination of suitable, carbon-based coatings with water- and oil-based lubricants. Possible applications are e.g. planetary gearboxes with high load and speed requirements. We performed Swinging Friction Wear Tests on DLC-coated 100Cr6-Steel. Friction and wear were recorded for different loads and temperatures as well as for different lubricants. First results of tribological tests are presented and the coating's performance is compared to performance at dry conditions as well as to conventional realizations with PFAS-containing lubricants. The long-term goal is the establishment of a knowledge-based database for coating-lubricant selection for a non-toxic environment, technological innovation, and the strengthening of industrial competitiveness.

P06 | The Concept of Improved HiPIMS Control Using a Synchronized Positive Bias Pulse

Kirsten Bobzin, **Max Philip Möbius**

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Physical Vapor Deposition (PVD) is increasingly employed for wear protection on components and tools, enhancing their lifespan and performance as its market share steadily grows. Residual stresses play a crucial role in this context. Industrial sputtering processes, such as High Power Impulse Magnetron Sputtering (HiPIMS), utilize process gases like argon to sputter atoms or ions from a target material that forms the coating layer. In addition to impacting the target, highly energetic argon ions also strike the growing coating due to applied bias voltage, leading to ion implantation that influences residual stresses. This can affect the mechanical properties and cutting performance of tools. During the pulse period of an HiPIMS process, the concentration of argon ions in the coating plasma changes.

In the “Bias Pulse” research project, a positive bias pulse is synchronized with the HiPIMS cathode pulse to control argon implantation and thus manage residual stress states. To analyze the impact of this positive bias pulse on plasma properties such as composition and ion energy, plasma diagnostics like optical emission spectroscopy, mass spectrometry, and retarding field analysis are employed. The results from plasma analyses are correlated with coating characteristics like residual stresses and chemical composition.

This research project aims to extend conventional HiPIMS process management by optimizing tool cutting performance through precise control of residual stress states. Consequently, small and medium-sized enterprises (SMEs) in industrial power supplies, PVD equipment manufacturers, producers of plasma diagnostics, and cutting tool manufacturers stand to benefit from future findings.

P07 | Digitalization of magnetron sputter processes for deposition of piezoelectric thin films

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In recent years, the significance of digitalization in sputtering processes has become increasingly apparent, particularly in the context of material science and thin-film depositions. The integration of digital technologies enables real-time monitoring and control of deposition parameters, leading to enhanced reproducibility and quality of the deposited films. The integration of machine learning algorithms can lead to even further improvements, enabling effective process and material development as well as superior process control.

However, a notable challenge remains: the limited availability of comprehensive datasets that can effectively train machine learning models for predictive analytics. This scarcity of data hampers the optimization of sputtering processes, as algorithms struggle to identify patterns and correlations without substantial historical data. The generation of comprehensive and qualified data sets requires considerable time and effort. Even then, not all relevant influences can be detected and quantified easily. In addition, the extensive characterization of the films (and devices further along on the value chain) most often is more time-consuming and expensive than the fabrication steps themselves.

In this poster presentation, we will show strategies for dealing with limited amounts of data in sputter process development and monitoring, developed in the BMFTR funded project “DigiMatUS”. Several steps are taken in the project. The development of a thin film ontology provides a structured presentation of domain knowledge. The symbolic knowledge of different domain experts and the developed thin film ontology are combined with machine learning methods to produce a neuro-symbolic model. This allows the explicit integration of meaningful limitations and dependencies, both quantitative and qualitative, that guide the machine learning approach. Thus, a more informed prediction model can be trained, even with limited data. The experimental data are gathered from deposition processes of piezoelectric AlScN thin films using reactive magnetron sputtering processes in a wider range of process parameters. The films are characterized by their structural, optical and piezoelectrical properties. These results are linked to process parameters and in-situ diagnostic results during depositions (e.g. gas flows, target parameters, plasma monitoring or in-situ reflectometry) and are then used to train the model.

P08 | Controlled Reactive Magnetron Sputter Epitaxy of GaN Using a Solid Ga Target

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Group-III nitrides are typically grown using established techniques such as metal-organic chemical vapor deposition (MOCVD), which produces high-quality films but relies on high growth temperatures and toxic precursor gases. In response to these limitations and the increasing demand for GaN epitaxial layers, alternative deposition approaches have attracted attention. Magnetron sputter epitaxy (MSE) stands out among these, offering distinct advantages over conventional growth processes, including improved sustainability, reduced operational costs, straightforward scalability, and higher throughput. Considerable prior work on MSE for GaN has utilized liquid gallium targets.¹ These studies revealed that liquid targets can lead to particle bursts directed toward the substrate, which may compromise crystal quality and film uniformity. Moreover, liquid targets often require maintenance after each deposition cycle before further coating can proceed. Recently, solid gallium targets have been demonstrated to overcome these obstacles under laboratory conditions, yielding high-quality GaN films.² Scaling up GaN MSE technology represents the next key milestone, demanding a fully controlled and stable sputtering process to ensure reproducible, homogeneous epitaxial GaN growth on substrates of industrially relevant dimensions.

This work presents recent results for high-rate MSE growth of GaN(0001) on sapphire Al₂O₃(0001) substrates using a Double Ring Magnetron (DRM) system developed by Fraunhofer FEP. The DRM was adapted for sputtering from a solid gallium target with a 144 mm diameter, maintained at -35°C during deposition. The method enables bipolar or unipolar pulsed DC sputtering in the transition zone between metallic and reactive modes, defined as controlled reactive magnetron sputtering. This approach allows a process window with reduced kinetic energy bombardment of the substrate, which enhances film quality while achieving high growth rates exceeding 1 nm/s. Comprehensive analysis of the deposited GaN layers demonstrates uniform film thickness and excellent crystalline quality (ω -FWHM of 0.46° and 0.67° for the 00.2 and 10.1 reflections) as well as a smooth surface (RMS 3.7 nm), all achieved through precise process control.

¹ M. Junaid et al., APL 98 (2011)

² K. Pinggen et al., Vacuum 220 (2024)

P09 | Advanced process control using double ring magnetron for polarity control in sputtered epitaxial AlN

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Progress in III-nitride epitaxial growth is crucial for achieving cost-effective, energy-efficient power electronics, and simplified polarity control in the wurtzite semiconductor family will facilitate the development of advanced high-performance devices. Magnetron sputter epitaxy (MSE) has emerged as a promising technique for III-nitride growth, recently gaining attention as an alternative to conventional Metal-Organic-Chemical-Vapor-Deposition (MOCVD)^{1,2} by offering the potential for high throughput, lower costs, and improved environmental compatibility. MSE also enables processing at reduced temperatures (<1000 °C), simplifying stress management and contributing to improved material quality and device reliability, with the added benefit of possible monolithic integration into the Si-CMOS process chain. On the laboratory scale, the deposition of device-grade AlN and GaN semiconductor thin films for power electronics using MSE has already been demonstrated.³ High-volume MSE requires meeting criteria such as high growth rates, minimal lattice damage, and uniform deposition on large-area substrates. In this work, we report recent advancements in high-speed AlN MSE performed on a 200 mm Si(111) platform, utilizing Double Ring Magnetron (DRM) technology developed by Fraunhofer FEP. The DRM system facilitates sputtering in the transition region between metallic and reactive modes by employing unipolar and bipolar DC pulse mode operation, referred to as controlled reactive magnetron sputtering. This enables a process window with reduced kinetic energy bombardment of the substrate, which enhances film quality while maintaining high deposition

rates. Importantly, we demonstrate for the first time that AlN epitaxial layer polarity (Al- or N-polar) can be directly controlled during growth, something that is not possible with MOCVD. Epitaxial Al- and N-polar AlN are sputter-deposited at rates exceeding 1 nm/s and substrate temperatures below 800 °C. Examination of the AlN layers reveals homogeneous film thickness (500 ± 25 nm), high crystalline quality (ω -FWHM of 0.6° and 0.9° for the 00.2 and 10.1 reflections), smooth topography (RMS 0.8–3 nm), uniform polarity (Al- or N-polar), and reduced residual film stress (1500 MPa and 800 MPa for Al-polar and N-polar, respectively), all achieved through precise process control.

¹ K. Pinggen et al., *Vacuum* 220, 112852 (2004)

² S. Neuhaus et al., *Surf.Coat.Tech.* 429, 127884 (2020)

³ A. Dadgar et al., *Phys.Stat.SolidiA* 220, 2200609 (2023)

P10 | Probe measurement technology MRP used in pulsed plasma processes

Moritz Oberberg¹, Birk Berger¹, Geoffrey Mellar¹, Kirsten Bobzin², Max Möbius², Stefanie Cirakman², Leon Schäfer², This Project is supported by the Federal Ministry for Economic Affairs and Energy (BMWE) on the basis of a decision by the German Bundestag.

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Physical Vapor Deposition (PVD) technologies, particularly **High Power Impulse Magnetron Sputtering (HiPIMS)**, are widely implemented in modern industrial manufacturing processes for the creation of advanced surface coatings. These coatings serve a variety of purposes, most notably to enhance the durability, lifespan, and functional efficiency of tools and components. At the heart of the HiPIMS technique lies the plasma, which plays a vital role in initiating and sustaining the deposition process, as well as generating the particles necessary for layer formation.

These layer-forming particles originate from a metallic target material. Often, reactive gases such as nitrogen or oxygen are introduced into the process to chemically modify the deposited layer and tailor its properties. Within the plasma, atoms and ions from both the target and the reactive gas are generated and subsequently transported to the surface of the substrate – the component or tool being coated. The plasma conditions directly impact the resulting film characteristics, including critical properties like indentation hardness.

A notable phenomenon observed in magnetron sputtering is the so-called **hysteresis effect**. When the reactive gas flow becomes too high, a non-conductive compound layer may form on the target surface, significantly decreasing the deposition rate and reducing overall process efficiency. Conversely, if the flow of reactive gas is insufficient, the resulting coating may exhibit a low ratio of reactive elements to metal, producing sub-stoichiometric films that often show inferior mechanical and functional properties, such as reduced hardness.

To ensure the stability and reproducibility of PVD processes, **plasma diagnostic tools** are essential. These diagnostics allow for real-time monitoring of plasma conditions, making it possible to adjust process parameters dynamically based on the behavior of the plasma. This leads to greater efficiency and reliability in coating outcomes. Moreover, by observing changes in plasma parameters that reflect, for example, target erosion, maintenance schedules can be optimized more precisely.

The objective of the present work is the development of a robust plasma diagnostic monitoring system tailored to industrial HiPIMS environments. For this purpose, a **Multipole Resonance Probe (MRP)** is adapted and further developed to enable phase-resolved measurements of key plasma parameters – namely **electron density** and **electron temperature**. These two quantities are fundamental to understanding and controlling plasma behavior. For the first time, this diagnostic approach is applied to HiPIMS, offering temporal resolution within individual pulse cycles.

The MRP operates based on the principle of **active plasma resonance spectroscopy**, exploiting the resonant response of electrons in the plasma to detect and quantify plasma parameters. The in-house developed electronics function as a complete vector network analyzer, allowing triggered acquisition with a time resolution as fine as 1 microsecond. Additionally, the probe can be equipped with a shutter mechanism to prevent unwanted metallic deposition on the sensor itself. As demonstrated in this study, both plasma dynamics and surface phenomena – such as **secondary electron emission** from the target and the **positioning of the probe** – significantly influence the measured plasma parameters.

S4-4 | Microstructure Characterization of Optical Systems exemplified by damaged Laser Mirrors

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Sub-microstructure diagnostics is one cornerstone of the nanostructure-based development of optical materials, like thin film-based optics. It is equally important when it comes to a detailed failure analysis of optical materials and optical systems.

State-of-the-art nano--analytics with respect to thin-film based optics can be used to answer questions related to layer thicknesses, homogeneity, purity, crystallinity, or substrate-film interface issues such as delamination or contamination.

As will be exemplified for laser-induced damage threshold (LIDT) – tested laser optical components, a detailed failure analysis benefits from a state-of-the-art nano--analytics workflow.

Laser optical components typically consist of an optical substrate that is functionalized with thin-film multilayers. Especially for future applications, such as laser inertial fusion, these components will be exposed to ever-increasing laser powers and need to be optimized regarding their lifetime and performance. The potential of state-of-the-art nano-analytics to reveal the causes and effects of laser induced damages are demonstrated, exemplified by the microstructural analysis of LIDT – stressed laser mirrors (HR mirror, R = 99.95% at 1064 nm) after testing. The combination of virtually artifact-free sample preparation, high-end analytical methods that deliver highest lateral resolution (e.g. transmission electron microscopy, TEM), and spectroscopical methods with very high detection sensitivity (e.g., time-of-flight secondary ion mass spectrometry, ToF-SIMS), give deep insights into the defect formation. Understanding the root causes of laser induced damage also forms the basis of the nanostructure-based development and improvement of thin film-based laser optics.

P11 | Effect of sinusoidal and bipolar-pulsed power delivery on dual magnetron sputtering processes

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Dual magnetron reactive sputter deposition of insulating materials is an industrial standard process. Historically, both AC sine-wave power supplies and bipolar pulsed (BP) square-wave power supplies have been extensively utilised to power the two targets alternately by periodically switching the polarity between the dual targets with a 50/50 time share.

Our experimental studies on reactive sputter deposition of SixNy using dual rotary Si targets indicated an ~10% higher deposition rate with the BP mode as compared with the AC mode at identical power and other operating conditions. Simulation studies were initiated to understand the fundamental differences in time-varying plasma behaviour between these two distinct plasma-driving waveforms, and how the differences impact deposition rate.

In this poster, we present the experimental results showing differences in the silicon nitride films deposited under similar controlled conditions using AC and BP power supplies operating at 10 kW and 40 kHz. In-depth simulation studies follow the experimental work by leveraging a hybrid multi-fluid plasma model to gain insight into the dynamics of the AC and BP driven sputter processes. The model describes both the dynamics of the plasma (electrons / ions) over the course of the periodic waveforms and the transport of the sputtered material from the target to the substrate. The deposition rate increase in the BP regime is attributed to 2 factors: (1) higher primary sputter flux from the target (caused by higher average ion energy in BP) and (2) more favourable plasma distribution, which suppresses re-deposition and cross-deposition of material. In addition to the deposition rate, the substrate heat load is quantified, showing no significant difference between BP and AC.

This work is part of a long-term research activity, where numerical models are being employed to understand the key differences in performance and behaviour of different MF power supplies in industrial plasma coating processes.

S3-3 | Structural Analysis of Carbon Thin Films Deposited In Ti-6Al-4V by the PIII&D Technique

Beiker M. Rueda¹, Fabio A. Xavier¹, Nazir Monteiro², This work was supported by the CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior) - PROEX (Programa de Excelência Acadêmica) - Brasil for financial support, LAS-INPE and LMP-UFSC for technical assistance.

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The aim of this study is to investigate the properties of carbon films coatings deposited on titanium alloy (Ti6Al4V) samples inside metal tubes in order to increase the corrosion resistance of its inner surface. These films were deposited by Plasma Immersion Ion Implantation and Deposition titanium alloy (PIII&D) system by driving Hollow Cathode (HC) discharges inside the tubes of titanium alloy (Ti6Al4V) [1]. The experimental results show an interesting change on the chemical structure and morphology of the as-deposited carbon films, when the diameter of tube varied. Therefore, the surface was evaluated by White Light Interferometry and Scanning Electron Microscopy (SEM). The chemical structure was analyzed by Raman Spectroscopy. In this study, the evaluation of the mean height deviation amplitude (Sa) and spatial density (Sdr%) showed significantly differences in the roughness parameters in tubes with different diameter, however, the different microtopography of surfaces obtained may be categorized as smooth (0.0–0.4 μm) [2]. This surface characteristic is related with the chemical structure, where the Raman spectra presented D and G peaks, characteristic of carbonaceous materials with crystalline and amorphous regions with different ID/IG ratios [3]. The results showed that the inner surface of the tube was completely coated by carbon films, as analyzed in the samples fixed along the tube.

S2-1 | Diffusion Welding of Surface-Treated Aluminum Plates Via Plasma Sputtering

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Aluminum is an interesting material for the fabrication of thermal devices due to its good relationship between mechanical and thermal properties. Further, as it is a very reactive metal with oxygen, it forms an extremely stable layer of aluminum oxide (Al₂O₃), which acts as a corrosion-resistant barrier. The diffusion welding process is highly recommended for the fabrication of thermal devices, but the layer of Al₂O₃ acts as a barrier for the diffusion process of aluminum. In this work, a surface treatment via plasma sputtering was performed to remove the Al₂O₃ layer (in situ surface activation) and to deposit a thin layer of copper to produce a coating with customized properties that facilitate the metallurgical consolidation by diffusion welding process in a vacuum furnace. To evaluate the influence of the surface treatment, the surface finish of the pairs samples to be joined was studied by white light interferometry. The morphological characteristics of the joint welded were analyzed by metallography, SEM and EDS tests. The results showed a joint with good integrity and absence of the intermetallic phases that could induce corrosive processes. Thus, demonstrating the viability of this diffusion welding process of aluminum for the fabrication of thermal devices.

S2-2 | PVD Coating for Plastic Processing Applications

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Nowadays, sustainability is no longer just a buzzword used to attract people's attention. Rather, sustainability is becoming increasingly important in both private and industrial environments. Recycling, an important aspect of sustainability, not only offers solutions such as improved resource utilization, but also presents challenges. One of these challenges is that recycled plastics exhibit changes in their properties, such as increased abrasiveness. In addition to sustainability, however, productivity and thus economic efficiency are also of crucial importance. High productivity can be achieved primarily through short cycle times. In the past, plastic processing tools were often used uncoated, which

led to long maintenance intervals, for example due to the cleaning of plastic residues, production rejects due to damaged or contaminated tools, or tool failures due to corrosive or abrasive damage.

One way to reduce the aforementioned challenges is to use PVD coatings. By combining different properties such as high corrosion resistance with good properties such as high indentation hardness, while maintaining a low coating thickness to preserve the shape contour accuracy of the tools, these coatings represent a promising solution. A Cr-based coating was therefore developed to maximize service life and extend maintenance intervals. This coating was applied using arc evaporation. BALINIT MOLDENA was developed to minimize adhesion and corrosion in contact with various plastics such as, Polyamid (PA), Polypropylene (PP), etc. Various coating characterizations such as the Rockwell test, scanning electron microscopy, and instrumented indentation testing were used to qualify the coating. The salt spray test was used to characterize the corrosion resistance. Finally, the demolding properties of various plastics from coated tools were also evaluated. This showed that a Cr-based coating leads to a significant reduction in the demolding forces required.

S2-3 | Properties of carbon coatings and applications

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Carbon coatings exhibit a variety of adjustable physical properties depending on their structural modification. By employing different PVD methods and precise tuning of process conditions, the desired properties can be achieved on a broad range of substrate materials such as metal, plastic, and glass. This versatility makes carbon a suitable material for diverse applications across multiple industries.

In this poster, we present scalable coating solutions for high-volume production, showcasing the properties, performance, and application cases of our carbon layers. Case studies demonstrate carbon coatings on metal and polymer substrates exhibiting enhanced tribological behavior and improved durability.

Furthermore, carbon layers offer a cost-effective alternative for reducing interfacial contact resistance in bipolar plates compared to noble metals. Our current results highlight the potential of carbon PVD coatings to meet the demanding requirements in this field.

S2-4 | Adhesion enhanced decorative coatings on ETFE - Combination of Plasma and Nanoimprint Roll-to-Roll processes for BIPV

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Fraunhofer FEP advances the coating of ETFE (ethylene tetrafluoroethylene) films by combining roll-to-roll nanoimprint lithography (NIL) with a tailored plasma pretreatment that overcomes ETFE's intrinsically low surface energy. Our work targets durable, large-area decorative coatings on ETFE films that can be laminated to glass and metal while preserving visual design freedom.

We engineered a web-based plasma step that nanoroughens the ETFE interfacial layer, enabling reliable anchoring of electron-beam-curable lacquer systems. Subsequently, a structured master roll imprints surface topographies from a few hundred nanometers up to the millimeter scale into acrylate lacquer; simultaneous e-beam curing fixes the features. The process is demonstrated at web widths up to 1250 mm and line speeds of several tens of meters per minute.

Adhesion on ETFE and in subsequent laminates to PV front glass and metallized façade sheets is significantly improved compared to untreated references. Together with project partners, the decorative film has been fabricated and applied to PV-active and non-active façade elements. In the BIPV use case, the films yield façades that are visually close to standard cladding while retaining up to 80% of the power of uncovered PV reference modules.

The poster will detail FEP's interfacial engineering, some basics of e-beam curing, and the R2R NIL process.

P12 | Effective transfer of high RF power with frequencies 13.56 MHz -81.36 MHz to plasma sources over long distances of up to 70 m

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The advantages of calculating RF power transmission systems for plasma applications are demonstrated using the example of the First Mirror Plasma Cleaning in the 55.E6 VSRS Visible Spectroscopy Reference System at the ITER Tokamak.

ITER- the International Thermonuclear Experimental Reactor is an international research project with the long-term goal of generating electricity from fusion energy. Fourteen different methods of optical in-situ plasma diagnostics in a vacuum are used for research. These systems feature optical complexity, with cable lengths that may extend up to 200 m between the measurement unit and the front optical mirrors positioned in the First Mirror Unit (FMU) within facing the plasma. Deposits that coat the mirror surface due to the fusion plasma are to be removed by RF plasma cleaning during planned maintenance cycles of the ITER reactor. Different plasma excitation frequencies between 13.56 MHz and 81.36 MHz can be used for different RF- cleaning technologies. Given the need to efficiently deliver power, as well as the considerable length of the RF power feeds, the first mirrors are executed as plasma electrodes with newly developed integrated impedance matching circuits (pre-matchers) positioned behind the first mirrors. This ensures optimal RF power transfer from the RF generator to the variable load impedance (electrode and plasma). These planar pre-matcher units consist of copper-coated ceramic plates.

The high-frequency transmission from the RF generators to the ports of the vacuum chamber housing first optical mirror units pass through multiple compartments equipped with various specialized RF coaxial cables, connectors and feedthroughs.

Extensive calculations and practical experiments are required in advance to obtain an optimally controllable RF power feed and to define the power limits of the systems. Equivalent RF models were developed using experimentally determined plasma impedances, exact component dimensions, and material composition.

Spatially resolved RF voltages, RF currents, and phase angles could be calculated. Results for pre-matcher tuning and RF line calculation are shown.

The advantage of such comprehensive high-frequency power loss calculations lies not only in the improved planning of complicated complex RF power supplies and the optimal selection of devices and materials (minimization of acquisition costs), but also in the overall optimization of power consumption and thus the reduction of CO₂ emissions.

S2-5 | Improvement of the adhesion force of sputtered aluminum layers on polyethylene terephthalate films (PET) by surface modification using flash lamp annealing

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It is well-known that a significant part of commercially available polyethylene terephthalate (PET) films are oriented and semi-crystalline. The biaxial orientation can be controlled during manufacturing when the foils are stretched in machine and transverse direction. This process strongly aligns the polymer chains in plane of the film, resulting in a layered structure of highly oriented layers parallel to the film surface with weak bonds into the bulk of the substrate. Therefore, the resulting film has a high strength in plane and weak strength in the thickness direction. This structure has been pointed out to be the reason for bad thin film adhesion. Deposited thin films show good adhesion to the polymer, but as the layered surface of the polymer has only weak bonding strength into the thickness direction, the first layers of PET can be removed together with the coated thin film. To overcome this problem the semi-crystalline structure needs to be modified.

A modification of PET film surfaces using flash lamp annealing (FLA) was investigated. By applying a short intense light pulse to the surface, the upper microns of the PET film were molten and solidified in the time of a few milliseconds. This ultra-fast process results in an amorphous surface showing no preferred orientation. To determine the change of the surface from semi-crystalline to amorphous the peaks of the CH₂-

CH₂ wagging (1342 1/cm) and C–O stretching (962 1/cm) transitions have been measured by FT-IR spectroscopy. The absorbance of both monitored transitions got almost to zero when changing into the amorphous state. This could be observed when applying an energy density of approx. 10 J/cm² to the PET films. The resulting amorphous surface has been coated with 90 nm of Aluminum. The achieved adhesion force measured by German wheel peel test is more than a factor of 10 higher compared to untreated PET.

Further experiments are planned to demonstrate the effect on R2R equipment by inline FLA and evaporation to validate the industrial relevance.

S3-4 | Depth profiling of near-surface effects in low pressure plasma-treated PDMS by VUV spectroscopic ellipsometry

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Low-pressure plasma is a versatile tool for surface engineering of polymeric materials. A wide range of effects can be achieved in the near-surface region while volume characteristics are preserved. Some applications are based on modification effects in the outermost molecular layer only, while others rely on a particular depth profile introduced by the plasma treatment. Addressing the latter case, the current study aims at 3D characterization of plasma-treated polydimethylsiloxane (PDMS).

Upon plasma exposure, the material undergoes a gradual conversion from a soft polymeric structure towards a more-stiff SiO₂-like structure. The range of this process is limited on a sub-micron scale. Depending on the properties of the applied plasma (ion energy distribution at the material surface, intensity and spectral distribution of ultraviolet photon emission) and the properties of the exposed polymer (atomic composition, binding energies, ultraviolet absorption behavior) a complex profile is formed which is hard to predict quantitatively.

To address this issue, we employed a range of complementary techniques like vacuum ultraviolet (VUV) spectroscopic ellipsometry, quantitative nano-mechanical mapping atomic force microscopy (QNM-AFM), and elastic recoil detection (ERDA). In case of VUV ellipsometry, the extended spectral range up to 8.5 eV allows for an optical model that considers a number of characteristic spectral features of PDMS related to the plasma exposure. It assumes a depth-dependent variation in refractive index in the near-surface region as well as a homogeneous part underneath (two-segment gradient model).

Furthermore we employed QNM-AFM and ERDA to explore the depth profiles of mechanical properties and atomic composition respectively. All diagnostic approaches were applied to the cases of low pressure O₂, H₂, N₂, and CO₂ plasma at different treatment times. As a unique outcome of this study, we were able to correlate distinct process parameters of a low-pressure plasma treatment to the depth dependent material properties in the near-surface region of a polymeric material.

S4-5 | Optical Emission Spectroscopy during Anodic Arc Deposition of Dielectric Films

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Deposition of functional thin films is a key technology in optoelectronic applications such as solar cells. Efficiency improvements are pursued through the use of novel coating materials, whose diverse chemical–physical properties present both opportunities and challenges. In particular, sensitive underlying layers must be protected from damage during the deposition of new films. High-energy particles can induce lattice defects through collision processes, thereby reducing device efficiency.

The anodic arc evaporator has proven to be a particularly gentle PVD technique, owing to its lower particle energies compared to other methods such as magnetron sputtering. By applying a positive potential to the electrically conductive evaporation target and employing magnetic fields, electrons are precisely accelerated toward the feedstock material, causing heating, evaporation, and ionization of the material.

Earlier publications have demonstrated the deposition of transparent conductive oxides (e.g., ITO) in combination with a hollow cathode. In this study, we have extended the application range to electrically insulating materials (Al₂O₃, MgO, SiO₂, Si₃N₄) and shown that these can be

successfully evaporated and deposited as transparent thin films. For plasma process monitoring and process control, an optical emission spectrometer was used as an indirect diagnostic method, since invasive plasma diagnostics risk interference when insulating layers build-up on the probes. From the emission spectra, the influence of deposition rate by varying the anodic discharge current intensities (25–70 A) and gas flows of O₂ and N₂ (0–200 sccm) on the evaporation plasma was systematically investigated.

S3-5 | Metallisation of Electrically Conductive Ceramics for Methane Dry Reforming Applications

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Electrically conductive ceramics are emerging as robust materials for high-temperature applications, including dry reforming of methane (DRM), where thermal and chemical stability are critical. In this work, we investigate the metallisation of conductive ceramic substrates to enable reliable electrical contacting in DRM reactor environments.

The ceramic materials studied offer excellent conductivity as well as thermal and chemical resistance, making them suitable for electrically assisted reforming processes. However, to integrate electrically conductive ceramics into functional reactor systems, stable and conductive metal contacts are essential. We examine how deposition induced stresses in the electroplated nickel layer influence adhesion and the thermal stability of the ceramic-metal interface.

The poster presents an overview of nickel electroplating on conductive ceramics with particular attention to internal stress management. Emphasis is placed on identifying process windows that enable low stress deposition and durable interfaces. These insights aim to support the design of robust and stable contacts for homogeneous heating of electrically conductive ceramic components in high temperature applications.

Our findings contribute to the development of electrically integrated ceramic components for DRM, paving the way for advanced reactor designs that leverage resistive heating. The work highlights the importance of interface engineering in enabling the next generation of energy-efficient and electrically driven reforming technologies.

S2-6 | Sputtering of UV blocking hard coatings for protecting plastics

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Plastics are ubiquitous in modern applications due to their versatility, lightweight nature, and cost-effectiveness. However, their susceptibility to wear and ultraviolet (UV) degradation poses significant challenges, especially in outdoor and high-performance environments. This poster explores the development and application of UV-blocking hard coatings designed to protect plastics from these detrimental effects. By integrating advanced materials and innovative coating technologies, these coatings enhance the durability and lifespan of plastic substrates.

The UV-blocking hard coatings are formulated using inorganic nanocomposite materials, which impart superior resistance to UV radiation and mechanical wear. The coatings were deposited by magnetron sputtering in optimized processing conditions to ensure strong adhesion and uniform coverage across the plastic surface. These coatings act as a barrier, effectively absorbing and reflecting harmful UV rays while providing a hard, protective layer against physical abrasion. Characterization studies demonstrate the coatings' excellent thermal stability and effectiveness in significantly reducing UV transmittance. Wear resistance tests further confirm the coatings' capability to protect against scratches and surface damage, making them ideal for applications in automotive, aerospace, and consumer products. In conclusion, UV-blocking hard coatings represent a promising approach to safeguarding plastic materials from wear and UV degradation, contributing to the advancement of durable and sustainable plastic products in various industries.

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