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Europäische Forschungsgesellschaft Dünne Schichten e. V.
European Society of Thin Films

Digital Booklet

INTERNATIONAL WORKSHOP

Plasma, Catalysis & Thin Films for Conversion Processes

April 29 – 30, 2025
Marl, Germany

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PROGRAM COMMITTEE

- **Annemie Bogaerts,** University of Antwerp, Belgium
- **Ronny Brandenburg**, Leibniz Institute for Plasma Science and Technology (INP), Germany
- **Robert Franke,** Evonik Operations GmbH, Germany
- **Andreas Schulz, Matthias Walker,** University of Stuttgart, Germany
- **Katrin Ferse**, EFDS, Germany

PROGRAM

Tuesday, April 29, 2025

Tuesday, April 29, 2025

09:00 | Opening

Session 1 | Introduction to Plasma Catalysis

Moderation: Ronny Brandenburg, Leibniz INP, Germany

09:15 | WS0101
Kinetics in plasma catalysis; perspective of a catalysis engineer
Leon Lefferts, University of Twente, Netherlands

09:45 | WS0102
Plasma catalysis: Knowledge gaps towards creating real synergy
Annemie Bogaerts, University of Antwerp, Belgium

10:15 | WS0103
Plasma-catalysis: gas phase kinetics, transport and in situ characterization of surface modifications at the nanoscale
Peter Bruggeman, University of Minnesota, USA

10:45 | Coffee Break

11:30 | WS0104
Industrial view from the host
Title to be announced
Jürgen Lang, Evonik Operations GmbH, Germany

Session 2 | Plasma catalysis from the catalyst's point of view

Moderation: Matthias Walker, University of Stuttgart, Germany

12:00 | WS0201
Development of catalysts for electrified processes utilizing ammonia as hydrogen carrier
Tim Nitsche, Fraunhofer UMSICHT, Germany

12:20 | WS0202
What should physicists active in plasma catalysis have in mind about what matters in thermos catalysis
Eric Gaigneaux, Molecular Chemistry, Materials and Catalysis (MOST), Belgium

PROGRAM

Tuesday, April 29, 2025

12:40 | Lunch Break

13:40 | WS0203
Consequences of non-thermal plasma stimulation on catalyst reactivity
Jason Hicks, University of Notre Dame, USA

14:00 | WS0204
Electrochemical PFAS degradation using boron-doped diamond electrodes made by plasma-enhanced chemical vapor deposition
Robin Kupec, W&L Coating, Germany

14:20 | WS0205
Plasma induced Reactions of small Molecules
Baoxin Zhang, LIKAT, Leibniz-Institut für Katalyse, Germany

14:40 | WS0206
Understanding NTP activated methanol synthesis and clean hydrogen production using in-situ methods.
Chris Hardacre, Manchester University, United Kingdom

*15:00 | Coffee & **Poster Break I***

Visit the Poster Session during this break. The poster presenters are asked to answer questions and be available for discussion. Use the chance and get in contact with the poster authors.

Session 3 | Plasma Gas Conversion

Moderation: Andreas Schulz, University of Stuttgart, Germany

15:40 | WS0301
Plasma conversion technology: from fundamentals towards industry
Ursel Fantz, Max Planck Institute for Plasma Physics, Germany

16:00 | WS0302
From renewable energy to valuable chemicals: plasma catalysis innovations in power-to-X applications
Jens Hofmann, MUEGGE GmbH, Germany

16:20 | WS0303
Obtaining CO rich gas streams from CO_2 point-sources
Christian Koch, enaDyne, Germany

16:40 | WS0304
Advancements in Electron Beam and Plasma Technologies for Sustainable Conversion Processes
Elizabeth von Hauff, Fraunhofer FEP, Germany

17:00 | WS0305
Thermal arc heated plasma technology for high temperature processes
Hamid Reza Yousefi, PlasmaAir, Germany

17:30 End

19:00 Get-Together at Restaurant Lipper Hof

19:00 | Get-Together @ Restaurant

Hotel Restaurant Lipper-Hof |
Lipper Weg 86, 45770 Marl

*Participation is included
in the Registration Ticket.*

SPEAKERS

Leon Lefferts

University of Twente, Netherlands

Leon Lefferts (1960) studied chemical engineering at the University of Twente (1983) and received his PhD in 1987 (University of Twente), and joined the DSM Research laboratories (1987-1999)

He was appointed full professor “Catalytic Processes and Materials” at the University of Twente in 1999. Current research interests include heterogeneous catalysis in liquid phase and activation of stable molecules like N2, H2O, CH4 and CO2 with catalysts and membranes and non-equilibrium plasma.

Kinetics in Plasma Catalysis; perspective of a catalysis engineer.

Kinetics of catalytic reactions is essential information for the design of chemical reactors and processes. This lecture will discuss how best practices in research on kinetics in heterogeneous catalysis could be tuned for application to plasma catalysis. Based on this analysis, opportunities and pitfalls for application of plasma catalysis for synthesis of fuels and chemicals will be discussed.

SPEAKERS

Annemie Bogaerts

University of Antwerp, Belgium

My research focuses on plasma chemistry, plasma reactor design and plasma-surface interactions (incl. solid catalysts, liquids and biomolecules), by computer modelling and experiments, mainly for applications in green chemistry (e.g., plasma-based CO_2 and CH_4 conversion, N_2 fixation for green fertilizer production, green H_2 synthesis,…) and plasma medicine (mainly cancer research).

I am head of the research group PLASMANT, which O founded from scratch and now counts ca. 50 members.

Plasma catalysis: Knowledge gaps towards creating real synergy

Plasma catalysis is gaining increasing interest for green chemistry applications, but the underlying mechanisms are far from understood, and plasma-catalyst synergy is not always observed. Hence, there is a need for better insights in the current limitations, and especially how to overcome them, in order to make progress in this emerging field. This talk will discuss the critical limitations, i.e., (i) lack of insight in the optimal catalyst material tailored to the plasma environment, leading to trial-and-error experiments often based on insights from thermal catalysis, (ii) the plasma conditions not being tuned to the catalyst needs and thereby non-optimal plasma activations of molecules, (iii) the need for improved plasma reactor design with better contact between plasma and catalyst, and (iv) the need for correct measurements and consistent reporting of the obtained results. We hope to inspire other researchers to collaborate in looking for solutions.

SPEAKERS

Peter Bruggeman

University of Minnesota, USA

Peter is a Distinguished McKnight University Professor and the Ernst Eckert Professor of Mechanical Engineering at the University of Minnesota. He currently also serves as the Director of Graduate Studies of Mechanical Engineering and the Director of the High Temperature and Plasma Laboratory. His research focuses on low temperature plasma science and engineering with applications in health and sustainability.

Plasma-catalysis: gas phase kinetics, transport and in situ characterization of surface modifications at the nanoscale

While applications of plasma surface interactions and plasma catalysis are advancing rapidly, the mechanistic understanding of these interactions is lagging mainly due to a lack of in situ diagnostic capabilities. We will show that the detailed experimental characterization of well-designed canonical reactors allows us to develop simplified models of complex plasma-substrate interactions leading to a detailed understanding of the key species involved in plasma-catalysis and the importance of transport processes. Furthermore, we highlight a newly developed diagnostic capability: operando environmental Transmission Electron Microscopy (TEM) in a plasma environment to probe the mechanism of iron oxide nanoparticle reduction. This approach has also great potential to contribute to the understanding of plasma-catalyst interactions.

SPEAKERS

Jürgen Lang

Evonik Operations GmbH, Germany

Dr. Jürgen Lang is Director in the Reaction and Polymer Technology department of Evonik Operations function "Next Gernation Technology.

After education in electronics and computer technology at Messerschmitt-Bölkow-Blohm and studies in high and highest frequency technology at Karlsruhe Institute of Technology Dr. Lang earned his doctorate in Plasma Catalytic Effects of Barrier Discharges from KIT-Institute of Physical Electronics.

83 Years of Plasma Technology at Evonik

Because of their sizable temperature and density ranges, plasmas find applications in many fields of research, technology and industry. The presentation do focus on 83 years of industrial/commercial plasma chemical synthesis application at Evonik and cover examples of plasma chemical synthesis of organic as well as inorganic materials - including metallurgy. Exemplary, the innovation process from plasma-based vehicle exhaust cleanup to modern fertilizer production will be shown.

SPEAKERS

Tim Nitsche

Fraunhofer UMSICHT, Germany

Tim Nitsche has been working at Fraunhofer UMSICHT since 2021 on the development of reactors and catalysts for electrified processes such as plasma catalysis using dielectric barrier discharge (DBD), gliding arc, and ohmic reactors. From 2017 to 2021, he completed his PhD on plasmachemical oxygen removal in coke oven gas via DBD. From 2013 to 2016, he was Project Manager at IBU-tec, developing pilot-scale calcination processes for inorganic materials.

Development of Catalysts for electrified processes utilizing ammonia as hydrogen carrier

Ammonia is a highly promising candidate for chemical hydrogen storage, offering high volumetric energy density and benefiting from established infrastructure. However, current technologies for hydrogen attachment and separation from ammonia are energy-intensive and only partially utilize renewable electricity directly. Additionally, the start and stop times of these technologies are not ideal for decentralized production sites.

These challenges are addressed in the Fraunhofer flagship project AmmonVektor, where innovative electrified processes are developed such as gliding arc plasma for ammonia synthesis and ammonia decomposition in an ohmic reactor.

For the success of both processes the development of suitable catalysts is crucial. This presentation will explore advancements in catalyst development for these electrified processes, highlighting current results and their implications for the future of hydrogen storage technology.

SPEAKERS

Eric Gaigneaux

Molecular Chemistry, Materials and Catalysis (MOST), Belgium

Eric Gaigneaux made his PhD in 1997 and worked from 1997-2000 as post-doc in Germany, Japan and Belgium. Since 2000 he is principal investigator at UCLouvain in Belgium. Since 2014 he became full professor. Eric Gaigneaux has expertise in preparation of heterogeneous catalysts (a.o. via non-classical plasma assisted precipitation, solution combustion synthesis, etc) with a control of their morphology at the nanoscopic scales, characterization under the operational in situ/operando conditions, and applications in (thermo)catalytic processes.

What should physicists active in plasma catalysis have in mind about what matters in thermo-catalysis ?

After a brief introduction of the expertise of our team in (thermo)catalysis, the concepts dictating the performance of solids in (thermo)catalytic processes will be reminded. Parameters impacting the diffusion and adsorption of the reactants on the solids will be addressed, while the different main (thermo)catalytic mechanisms will be described. The objective is to tentatively spotlight the elements that should be taken into consideration when designing solids to be operated as heterogeneous catalysts under plasma conditions.

SPEAKERS

Jason Hicks

University of Notre Dame, USA

Jason Hicks is the Tony and Sarah Earley Collegiate Professor of Energy and the Environment in the Department of Chemical Engineering and Associate Dean for Graduate and Postdoctoral Affairs at the University of Notre Dame. He received his Ph.D. in Chemical Engineering from the Georgia Institute of Technology. His research program targets the precise synthesis and characterization of catalytic materials and the development of plasma-assisted processes for the production of chemicals and fuels.

Consequences of Non-Thermal Plasma Stimulation on Catalyst Reactivity

Non-thermal plasma catalysis drives chemical transformations under mild conditions with electrical energy. Catalysts in plasma systems can enhance rates at ambient temperatures and pressures, but plasma-phase reactions often dominate, and plasma exposure can alter catalyst structure. Sequential dosing separates plasma-phase and surface-mediated reactions, providing insights into plasma-stimulated surface processes. This presentation highlights two cases: 1) nitrogen plasma stimulation of metal catalysts followed by thermal reactions with hydrogen or oxygen to produce ammonia or NO_x, and 2) characterization of hydrogen plasma-treated catalysts to study structural changes. Plasma activation generates reactive surface nitrogen species for coupling with gases, with desorption peaks dependent on the metal catalyst. Hydrogen plasma can induce strong metal-support interactions at low temperatures, demonstrating the potential impact of plasma on catalyst structure and behavior.

SPEAKERS

Robin Kupec

W&L Coating, Germany

Robin Kupec is Manager for Diamond Electrochemistry at W&L Coating Systems GmbH since September 2024, working on reactor and process development, electrochemical wastewater treatment, and coating technologies. From 2019 to 2024, he was a PhD student and research associate in electrochemistry at DECHEMA Research Institute. He holds a M.Sc. and B.Sc. in Chemistry from J. W. Goethe University Frankfurt.

Electrochemical PFAS degradation using boron-doped diamond electrodes made by plasma-enhanced chemical vapor deposition

Environmental contamination with per- and polyfluoroalkyl substances (PFAS) emitted mainly by the chemical industry and consumer goods is an ongoing concern in wastewater treatment. PFAS are highly resistant to photolytic, chemical, and biological degradation and, therefore, impossible to remove with conventional wastewater treatment plants.

Electrochemical advanced oxidation processes (EAOPs) provide an environmentally friendly way to treat wastewater by mineralizing PFAS. Boron-doped diamond (BDD) electrodes are ideally suited for the anodic degradation of PFAS in aqueous media because they generate hydroxyl radicals and directly oxidize the very stable C-F bond.

Plasma-enhanced chemical vapor deposition (PECVD) is a cost-effective process for coating substrates with BDD. The method uses microwave plasma, which allows for low deposition temperatures. Apart from the low energy consumption, this results in reduced thermal stress and, thus, a wide range of possible substrates.

SPEAKERS

Chris Hardacre

Manchester University, United Kingdom

Chris Hardacre is Head of the School of Natural Sciences at the University of Manchester and a Professor of Chemical Engineering. In 2013 was the inaugural winner of the IChemE's Andrew Medal for catalysis, in 2022 won the Tilden prize from the RSC and in 2024 won the RB Anderson Prize from the Canadian Institute of Chemistry. His group has strong research interests in heterogeneous catalysis, ionic liquids and developing in-situ techniques to study structure-property relationships.

Understanding NTP activated methanol synthesis and clean hydrogen production using in-situ methods.

In-situ techniques have been used widely to study and understand heterogeneously catalysed reactions; however, few have been adapted for use with non-thermal plasma (NTP) activation. This talk will describe the development of diffuse reflectance infrared spectroscopic and X-ray absorption spectroscopic methods coupled with NTPs for the in-situ study of gas phase catalysis. Methanol production from CO_2, methane oxidation and the water gas shift reaction will be used to illustrate their use to probe the structure-activity relationships.

SPEAKERS

Ursel Fantz

Max Planck Institute for Plasma Physics, Germany

Low temperature plasmas physics with focus on diagnostics of molecular plasmas. Emphasis is given on the development of large and powerful negative hydrogen ion sources for neutral beam systems of ITER and on plasma conversion technology. Modelling activities are always closely linked to the experiments. The interests range from fundamentals to applications towards prototype developments combining physics with engineering issues.

Plasma conversion technology: from fundamentals towards industry

The variety of available plasma reactor concepts used for plasma conversion technology offers the possibility to adapt the plasma to the selected conversion process. While conversion in microwave plasmas at atmospheric pressures is governed by thermal processes, DBD and low-pressure microwave plasmas offer additional reaction channels due to the involvement of electron-driven processes, which are compatible with optional support by plasma (assisted) catalysis. As a prominent example, CO2 splitting is in the focus, since it is currently the furthest in terms of technological development and is compared to electrolysis. On a more fundamental level, dry reforming of methane, directly producing CO and H2, known as syngas, and methane pyrolysis for production of H2 and solid carbon are addressed. Aspects that need to be considered for potential industrial applications, such as process interfaces, gas separation steps, and possibilities for upscaling are also analyzed.

SPEAKERS

Klaus-Martin Baumgärtner

MUEGGE GmbH, Germany

Dr. Klaus Martin Baumgaertner, CEO of MUEGGE Group, is a physicist and inventor specializing in microwave and plasma technology. He earned his PhD at the University of Stuttgart and holds several patents in his field. As an expert, he contributes to scientific publications and innovations in plasma and microwave processes. He joined MUEGGE in 2000 and became CEO in 2012.

From Renewable Energy to Valuable Chemicals: Plasma Process Innovations in Power-to-X Applications

The transition to all-electric industrial processes is key for clean energy. Power-to-X technologies convert surplus electricity into carbon-neutral fuels and raw materials, with plasma catalysis playing a crucial role. Plasmas operate at various pressures, offering on-demand, modular solutions. Microwave plasma stands out for high efficiency, ionization, and minimal contamination. It supports diverse applications like CO_2 dissociation, hydrogen production, and fertilizer synthesis. MUEGGE's high-power microwave plasma sources drive these innovations.

SPEAKERS

Christian Koch

enaDyne, Germany

A chemical engineer by training, I'm CTO and founder of enaDyne. I'm specialized in plasma technology for emission reduction and chemical synthesis since 2004. My expertise includes advanced electrodes with novel surface and material properties for plasma applications, as well as plasma physics. At enaDyne, I lead an interdisciplinary approach to commercializing plasma catalysis, integrating expertise in materials, plasma engineering, catalysis, simulation, AI, prototyping, and testing.

Obtaining CO rich gas streams from CO_2 point-sources

Non-thermal plasma can dissociate CO_2 into CO and reactive O*, but steady-state conversion takes-place at a certain specific energy input due to O* back-reaction, causing energy losses. Optimized catalysts, such as those with oxygen vacancies, can suppress this effect, while nanosized metal oxides (e.g., NiO) enhance it. However, even the best catalysts don't achieve commercially viable CO_2 conversion. Introducing CH_4 improves efficiency by quenching O* and increasing syngas (CO + H_2) yield, yet dry reforming in DBD reactors also faces conversion limits. Overcoming these requires both optimized catalysts and intelligent reactor designs. V-DBD reactors are constrained by Paschen's law, while S-DBD reactors allow for industrial-scale flow geometries. Key challenges include optimizing gas-plasma-catalyst interaction and ensuring electrode stability under high-energy input. enaDyne is developing a full-scale concept for industrial DBD applications, including custom plasma generators.

SPEAKERS

Elizabeth von Hauff

Fraunhofer-Institut für Elektronenstrahl- und Plasmatechnik FEP, Germany

I studied Physics at the University of Alberta and completed my PhD and Habilitation at the University of Oldenburg. In 2011 I joined the University of Freiburg and Fraunhofer ISE. From 2013-2021 I was an Associate Professor at VU Amsterdam and became a special Chair in Chemistry at the University of Amsterdam in 2020. In 2021 I was appointed director of Fraunhofer FEP and Professor of Electrical Engineering at TU Dresden. My research focuses on fundamental questions in real-world applications.

Advancements in Electron Beam and Plasma Technologies for Sustainable Conversion Processes

The Fraunhofer FEP focuses on innovative technologies in electron beam and plasma processes. We aim to advance solutions for materials processing, catalysis, and environmental applications, contributing to sustainability and energy efficiency in various industrial and environmental applications. I will present case studies on flash lamp annealing for tailored surfaces, including plasmonic surfaces for photocatalytic water splitting and antipathogenic coatings for touchscreens. We'll also discuss photocatalytic semiconductor oxides for surface cleaning, plasma catalytic synthesis of functional materials, and gas conversion processes utilizing electron beam-assisted plasmas. Lastly, I will explore plasma-treated liquids for cleaning and disinfection, providing a sustainable alternative to traditional methods.

SPEAKERS

Hamid Reza Yousefi

PlasmaAir AG, Germany

Hamid Reza Yousefi received his PhD in Plasma Engineering in 2008 in Japan and has over 17 years of experience in both academia and industry. His expertise lies in arc-heated plasma technologies for high-temperature applications. He also has extensive experience in clean energy production through fusion devices, with a recent focus on plasma burner development. As a senior scientist at PlasmaAir AG, he is responsible for multiple R&D projects, including the development of low- and high-power plasma torches (steam, CH_4, CO_2, air, etc.). He currently leads the development of a hybrid CH_4 + H_2 plasma burner within the GIFFT project, supporting the transition to clean and electrified industrial processes.

Thermal arc heated plasma technology for high temperature processes

Arc-heated plasma torches are key enablers of electrified, high-temperature industrial processes. This presentation focuses on the development of steam plasma torches for gasification, as well as CH_4 + H_2 plasma torches for applications including electrification in the glass industry, methane pyrolysis, and CO_2 conversion. These technologies provide efficient pathways for hydrogen and syngas production. The talk offers an overview of ongoing development efforts at PlasmaAir AG, highlighting practical challenges in torch design and operation, along with considerations for process optimization and industrial scalability.

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PROGRAM

Wednesday, April 30, 2025

Wednesday, April 30, 2025

09:00 – 12:00
Guided Tours | please choose one!

Tour A - Evonik – Chemistry Park in Marl
Lipper Weg 235, 45772 Marl |
Information Center
Presentation of production plants and infrastructure facilities at the chemistry park in Marl directly next to the event location

09:30 Meet at Information Center
10:00 – 11:30 | Guided Bus Tour
11:30 Back to event location

Tour B – Fraunhofer UMSICHT
Osterfelder Straße 3 | 46047 Oberhausen

Overview of the current main research areas at Fraunhofer UMSICHT, having the opportunity to take a behind-the-scenes look during a laboratory and pilot plant tour, and thus get an insight into the equipment, research and development opportunities.

08:00 | Meet in front of Feierabendhaus
08:15 | Bus transfer to Fraunhofer UMSICHT
09:00 | Arrival & Welcome
09:30 | Laboratory and pilot plant tour
10:30 | Discussion
11:00 | Tour back to Feierabendhaus

12:00 | Lunch break at Event Location Feierabendhaus, Marl

13:00 Start of Workshop – Day 2
Event Location, Feierabendhaus, Marl

Session 4 | Plasma Catalysis Interactions & Applications

Moderation: Annemie Bogaerts, University of Antwerp, Belgium

13:10 | WS0401
Plasma-catalytic CO_2 methanation: results and scale-up potential
Tony Murphy, CSIRO, Australia

13:30 | WS0402
Stability of metal-organic frameworks in non-thermal atmospheric plasma
Jan Benedikt, University Kiel, Germany

13:50 | WS0403
Plasma-sorbent system for CO_2 capture and conversion
Sirui Li , University of Eindhoven, Netherlands

14:10 | Coffee & **Poster Break II**

15:00 | WS0404
Process considerations for plasma-based nitrogen fixation
Kevin Rouwenhorst, University of Twente, Netherlands

15:20 | WS0406
Challenge plasma catalysis - does the plasma enhance catalysis or does the catalyst enhances the plasma?
Achim von Keudell, Ruhr-Universität-Bochum, Germany

15:40 | Round Table Discussion

What is needed to create real plasma-catalyst synergy?
Moderation: Ronny Brandenburg, Leibniz Institute for Plasma Science and Technology (INP), Germany

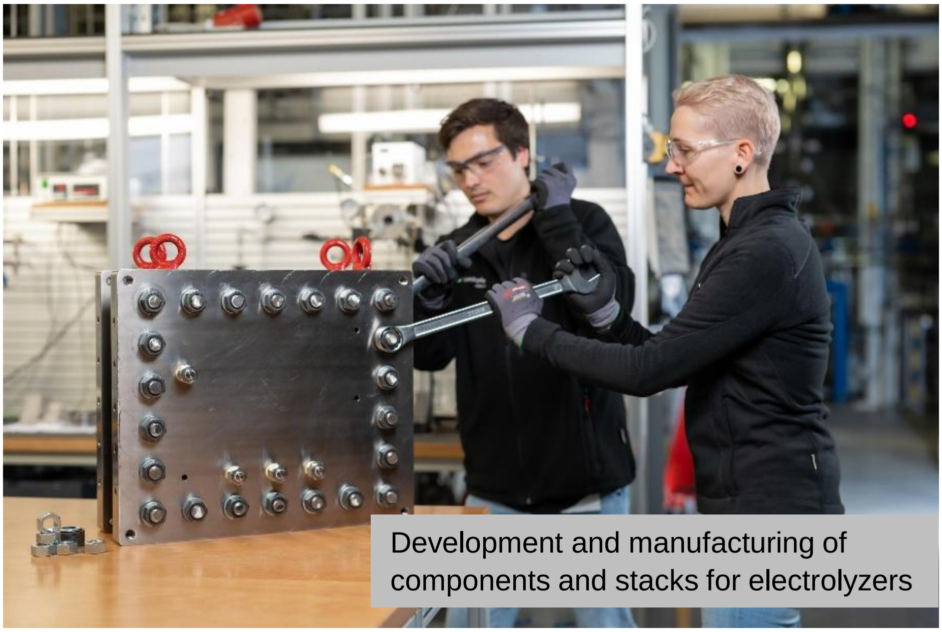
16:30 | End of Workshop

Excursion

Excursion to the Fraunhofer Institute for Environmental, Safety, and Energy Technology - UMSICHT, Oberhausen

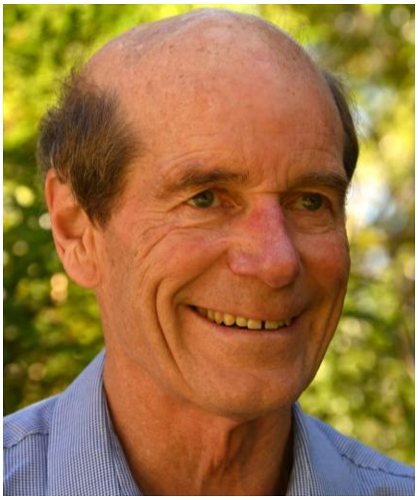
Fraunhofer UMSICHT is actively involved in shaping energy and raw materials management, focusing its research on four main areas: Carbon Management, Circular Economy, Green Hydrogen, and Local Energy Systems. Catalysis is an important cross-sectional technology that enables resource-efficient and energy-efficient production while reducing harmful emissions. Fraunhofer UMSICHT emphasizes electrocatalysis and heterogeneous thermal catalysis.

During the excursion, you will gain an overview of the current main research areas at Fraunhofer UMSICHT, have the opportunity to take a behind-the-scenes look during a laboratory and pilot plant tour, and thus get an insight into the equipment and research and development opportunities.



Development and manufacturing of components and stacks for electrolyzers

SPEAKERS



Tony Murphy

CSIRO, Australia

Tony has been with CSIRO, Australia´s leading government research organization, since 1989. He works on developing plasma applications, including plasma catalysis and hydrogen plasma ironmaking. He has received several awards for his research, most recently the 2024 Plasma Physics Innovation Prize of the European Physical Society. He holds editorial positions with five international journals, including Editor.in-Chief of Plasma Chemistry and Plasma Processing.

Plasma-catalytic CO_2 methanation: results and scale-up potential

Plasma-catalytic CO_2 methanation is a promising approach for producing methane from CO_2 or biogas using renewable energy. Experiments in a packed-bed dielectric barrier discharge (DBD) reactor using a nickel catalyst exhibit competitive methane yield, selectivity and energy efficiency to the thermal catalytic process but at a much lower temperature. In-situ DRIFTS measurements provide insights into the influence of the support material on the reaction mechanism. However, the scale-up of packed-bed DBD reactors is problematic because of the pressure drop associated with the packed bed. A new reactor design has given an even better performance (80% CO_2 conversion, 100% CH_4 selectivity, 67% fuel production efficiency) that is maintained at increased reactant flow rates.

Results will be presented for CO_2 and biogas conversion with the packed-bed DBD and new reactors, and the influence of the support material will be analyzed using the results of DRIFTS and other measurements.

SPEAKERS

Jan Benedikt

University Kiel, Germany

Prof. Benedikt is focusing in his research on the characterization of plasma chemistry in low-pressure and atmospheric plasmas with mass spectrometry being the main diagnostic tool for detection of ions and neutrals. Studied plasmas and plasma processes are utilized in thin film deposition, nanoparticle synthesis, surface or liquid treatment, or plasma catalysis applications.

Stability of Metal-Organic Frameworks in non-thermal Atmospheric Plasma

Metal-organic frameworks (MOFs) are promising candidates for plasma catalysts due to their flexibility and high porosity, where the plasma operation at atmospheric pressure and lower temperature compared to thermal catalysis avoids the issues with their sensitivity to high temperatures. It is, however, still necessary to test and understand the interaction of MOFs with conditions encountered in the atmospheric plasmas. Therefore, stability of nine MOFs in direct contact with non-thermal atmospheric plasma has been thoroughly tested at several temperatures and prolonged times. These MOFs have been carefully selected to test the effect of the MOF morphology and the selection of the metal centers and organic linkers on their stability. The set of stable MOFs have been identified as potential candidates for catalyst development. Additionally, in situ X-ray diffraction analysis of MOFs in contact with plasma has been performed at the European Synchrotron Radiation Facility (ESRF).

SPEAKERS

Sirui Li

University of Eindhoven, Netherlands

Dr. Sirui Li works in the field of plasma-based processes for sustainable energy and chemical production. His expertise lies in integrating advanced plasma technologies with material systems to tackle critical challenges in energy transition and carbon neutrality. He currently leads a team focused on developing novel plasma-material systems for process integration and intensification, with a strong emphasis on $CO2_2$ utilization, nitrogen fixation, and methane conversion.

Plasma-sorbent system for CO_2 capture and conversion

Plasma technology has emerged as a promising approach for CO_2 conversion, with significant progress made in the development of plasma reactors and plasma-catalytic systems in recent years. This talk introduces a novel concept of a plasma-sorbent system, which enables the simultaneous desorption and conversion of CO_2 within a single reactor. This approach opens new avenues for integrated processes for carbon capture and conversion by plasma. The presentation will delve into the mechanisms governing plasma-sorbent interactions with various sorbent materials, emphasizing distinct desorption pathways. Recent advancements in plasma-sorbent systems will be highlighted, including sorbent selection and modification, reactor designs, and optimized operation strategies. Key examples include periodic plasma ignition for improved energy efficiency and multi-reactor configurations enabling continuous operation and effective recycling of unreacted CO_2.

SPEAKERS

Kevin Rouwenhorst

University of Twente, Netherlands

Kevin Rouwenhorst graduated with a degree in Chemical & Process Engineering from the University of Twente in 2018. He received his PhD on 'Plasma-catalytic ammonia synthesis' from the University of Twente under supervision of prof. dr. ir. L. Lefferts in 2022. Currently, he works at the Ammonia Energy Association as Technology Manager, and he holds a position as Industrial Fellow at the University of Twente.

Process considerations for plasma-based nitrogen fixation

This talk will focus on pathways for plasma-based nitrogen fixation, and their potential industrial relevance, including emerging competing technologies. Strategies for improving the energy efficiency for plasma-based nitrogen fixation pathways are presented, as well as the most feasible pathways. Thermal-catalytic and electrochemical alternatives are also presented, showcasing the importance of heat integration between process steps.

SPEAKERS

Achim von Keudell

Ruhr-Universität-Bochum, Germany

Prof. Achim von Keudell is Professor in experimental physics at Ruhr University Bochum working on various aspects of plasma surface interaction in low and atmospheric pressure plasmas. His working topics include magnetron sputtering, plasma catalysis, microwave plasma for gas conversion, plasma etching and plasma deposition.

Challenge plasma catalysis - does the plasma enhance catalysis or does the catalyst enhances the plasma?

The field of plasma catalysis is driven by the aim of improving the conversion and/or selectivity of a plasma process through its integration with a catalytic active surface. In recent years, both synergisms and anti-synergisms between plasma and catalysis have been observed; however, these measured conversion rates fall behind the anticipated enhancement factors suggested by microkinetic modelling. In many instances, radicals prevail, and traditional catalytic reaction schemes that involve vibrationally excited steps may not represent the rate-limiting step. In this contribution, several examples are presented where a catalyst enhances the selectivity of a plasma chemical process or where a catalyst improves plasma performance, leading to a higher turnover rate of plasma chemical reactions.

SPEAKERS

Ronny Brandenburg

Leibniz-Institute for Plasma Science and Technology (INP)

Ronny Brandenburg fields of research are the breakdown and plasma chemistry in atmospheric pressure plasmas.

He graduated in physics at the University of Greifswald where he also received his PhD (Dr. rer. nat.) in experimental physics in 2005. Since 2008 he is with the Leibniz Institute for Plasma Science and Technology. In 2015 he obtained the habilitation at University of Greifswald and in 2017 he was appointed as full professor at the University of Rostock.

Round Table Discussion

What is needed to create real plasma-catalyst synergy?

Program Committee & Moderator of the Round Table Discussion with the well-known experts:

- Leon Lefferts, University of Twente, The Netherlands
- Achim von Keudell, Ruhr-Universität-Bochum, Germany
- Anthony Murphy, CSIRO, Australia
- Annemie Bogaerts, University of Antwerp, Belgium
- Peter Bruggemann, University of Minnesota, USA
- Robert Franke, Evonik, Germany

Poster Session

There is a lot of research and development activities around Plasma technologies and catalysis processes. Two Poster Session will take place on Tuesday, April 29, 2025, at 15:00 and on Wednesday, April 30, 2025, at 14:10 in the afternoon. Posters will be visible over the whole event.

PO001

Conversion of O_2 into CO by combined CO_2 plasma + heat exposure of carbon at low vacuum

E. J. Devid, DIFFER, Netherlands

To remove O_2 from the effluent of plasma CO_2 dissociation, carbon can be added downstream of the plasma. This work attempts to experimentally reveal the mechanisms and show how reacting the byproduct O_2 with solid carbon can produce additional CO.
In a low vacuum, the carbon is heated and exposed to the products of a non-thermal inductively coupled Radio Frequency (RF) CO_2 plasma. Through the usage of isotopic carbon13 and modeling of the mass spectrometry data, the different processes operating (i.e. $C + ½ O_2 \rightarrow CO$ versus $CO + ½ O_2 \rightarrow CO_2$ and $CO_2 + C \rightarrow 2\,CO$ (i.e. the reverse Boudouard reaction)) are disentangled. It is observed that the reaction: $C + ½ O_2 \rightarrow CO$ dominates and that three times more CO is produced than CO_2 under consumption of O_2.
This potentially opens a new way toward O_2 removal from the effluent of the CO_2 plasma dissociation processes where a clean CO_2/CO gas stream is generated via usage of “biogenic” carbon.

PO002

NO_x formation via electrically driven microwave plasma enhanced by heterogeneous catalysis

Jonas Gans, DIFFER, Netherlands

In this study, we investigate NO_x production and energy cost in a microwave (MW)-driven atmospheric pressure plasma system combined with a downstream catalyst, using ex-situ FTIR spectroscopy. Our analysis highlights potential mechanisms for plasma-enhanced NO_x formation on the catalyst surface. The results reveal that interactions between plasma-activated nitrogen and oxygen with the catalyst surface are likely key drivers of NO formation and its further oxidation to NO_2. Key parameters are discussed, including catalyst amount, plasma-catalyst distance, and catalyst temperature. More catalyst and relatively shorter plasma-catalyst distances yield better NO_x conversion, and the temperature optimum was narrowed down to 200-540 C, limited by a strong temperature gradient in the catalyst bed, induced by the warm MW plasma effluent. This work shows promising evidence of a catalyst-enhance MW-plasma process, for CO_2-neutral NO_x production.

Poster Session

PO003

Microwave plasma-based dry reforming of methane: Showing the role of radical reactions in the afterglow

Lex Kuijpers, DIFFER, Netherlands

An investigation of methane addition to CO_2 microwave discharges is presented. Experimentally, 0-30% CH_4 was added to CO_2 discharges operated at 150 to 900 mbar to investigate the overall chemistry and plasma properties. Results include the effluent gas composition, plasma core gas temperature and optical emissions. Addition of only 1% CH_4 is found to diminish the CO_2 conversion and decrease the energy efficiency significantly, while barely changing discharge characteristics. For larger additions of CH_4, the effluent composition and especially the selectivity are found to be independent of the plasma properties.

A quasi-1D chemical kinetic model is implemented for the afterglow. The experimentally found selectivity can be accurately reproduced by the model. Radicals are found to catalyse the recombination of CO and O_2, as well as drive the water gas shift reaction. It is shown that the overall chemistry is nearly completely controlled by radical reactions in the cooling trajectory.

PO004

Elucidating the role of oxygen vacancies in plasma-catalysis

Joran Van Turnhout, University of Antwerp and Eindhoven University of Technology, Netherlands

Although plasma catalysis has gained great interest from an increasing number of researchers, both in the field of plasma chemistry and catalysis, many questions concerning the fundamentals lying at the basis of plasma catalysis still remain. One of these questions pertains to the role of oxygen vacancies (OVs) in plasma catalysis. While their role has been somewhat speculated on, systematic studies are lacking. In this work, we systematically vary the OVs of CeO_2 by various pretreatments, to elucidate the potential role of oxygen vacancies in CO_2 hydrogenation. We explore both the chemical and physical roles of OVs, and monitor the evolution of OVs in plasma using in-situ FTIR.

Poster Session

PO005

Power Input of Pulsed Electron Beam Sustained Atmospheric Pressure Plasma for Gas Conversion

Lars Dincklage, Fraunhofer FEP, Germany

Non-equilibrium plasmas offer high flexibility and selective energy transfer for gas conversion processes such as CO_2 splitting or nitrogen fixation. However, their economic feasibility is limited by the challenge of combining high energy efficiency with high conversion rates at atmospheric pressure. These limitations can be addressed using non-self-sustained plasmas, in which an electron beam maintains a low-field plasma. This enables efficient vibrational excitation and dissociation at low reduced electric fields. Ionization is solely driven by the electron beam, while most reaction energy is supplied by a superimposed electric field discharge. Pulsed operation enhances the non-equilibrium character and prevents plasma contraction. Based on this principle, a plasma-chemical reactor was developed, and its power deposition evaluated with regard to its applicability in gas conversion processes.

PO006

How to avoid catalyst deactivation by soot deposition.

Callie Ndayirinde, PLASMANT, University of Antwerp, Belgium

The deposition of soot on catalyst surfaces is a major deactivation pathway in (plasma) catalysis. It can block the active sites and pores, reducing catalyst effiency and necessitate frequent regeneration or replacement of the catalyst bed. However, in plasma-assisted hydrocarbon conversion, soot or solid carbon is a common byproduct. Therefore, in this study a rotating gliding arc (RGA) plasma reactor, is used to investigate methods to suppress soot formation during plasma methane reforming. Specifically, the effect of additives, SEI, DC vs AC current and quenching on the formation of soot are investigated.

Poster Session

PO007

Methane oxidation inside a DBD reactor: Effect of catalysts

Abhinash Kumar Singh, University of Easter Finland, Finland

The objective of this study was to investigate methane oxidation in: an empty dielectric barrier discharge (DBD) reactor and a packed-bed DBD (PB-DBD) reactor containing various catalysts (1%Co/Al_2O_3, 1%Cu/Al_2O_3, 1%Fe/Al_2O_3, 1%Pt/Al_2O_3, and 1%Pd/Al_2O_3). In the empty DBD reactor, methane conversion was initiated at 23 W plasma power and increased with increasing plasma power. The main methane oxidation products were CO and CO_2. Both CO_2 selectivity and energy efficiency improved with increasing plasma power. However, methane conversion, CO_2 selectivity, and energy efficiency declined as the gas flow rate was increased. In the packed-bed DBD reactor, methane conversion was lower than in the empty reactor. The presence of catalyst increased the plasma power requirements for methane conversion. The presence of catalysts improved CO_2 selectivity, with Pd and Pt catalysts achieving above 90% CO_2 selectivity. Both Pd/Al_2O_3 and Co/Al_2O_3 improved energy efficiency compared to the empty reactor.

PO008

Single Wall Nanotube and Iron Nanoparticle Composite Synthesis via Steam Plasma Catalytic Pyrolysis of Methane

Jafar Fathi, Institute of Plasma Physics, Prague

In this study, we integrated an entrained flow reactor with a 100-150 kW DC steam plasma torch. Methane (60-100 SLM) was used as the hydrocarbon source, while Iron Oxide micropowder served as a catalyst. The resulting products were single-wall carbon nanotubes (CNTs) mixed with iron nanoparticles (~10 nm), characterized using HRTEM and Raman spectroscopy. Gas analysis via GC/MS showed a composition of 80% hydrogen and 20% CO, excluding argon. Introducing iron oxide into methane plasma pyrolysis influenced carbon formation, suggesting that iron nanoparticles facilitated CNT growth. The initial Iron Oxide particles fragmented into smaller pieces (<20 nm), likely due to thermal shock in the plasma environment.

Poster Session

PO009

In situ analysis of Ce(IV)-MOFs during Plasma Treatment using XRD and XAS at ESRF

Alexander Quack, Christian-Albrechts-Universität zu Kiel, Germany

The utilization of non-thermal atmospheric pressure plasmas, to supplement the existing chemical industry by using access renewable resources, allows for the potential usage of less heat resilient catalysts like metal-organic-frameworks (MOFs). Here, some MOFs are observed to be stable at conditions of non-thermal plasmas, while other MOFs are not. The exact processes of changes or decomposition of the MOFs has not directly been investigated.
We have developed a dielectric barrier reactor with an open optical axis to allow for in situ x-ray analysis of material within the plasma. The plasma operates with H_2 gas combined with Ar or CO_2 at 20 kHz at 8-15 kVpp and can be externally heated up to 200 °C. This design was employed during the beam-time of CH-7281 at BM-23 at the European Synchrotron Radiation Facility (ESRF) to treat MOFs containing cerium. The chemical stability of these compounds was analyzed using in situ x-ray diffraction (XRD) and x-ray absorption spectroscopy (XAS).

PO010

Synthesis of Carbon-Based Materials by Methane Pyrolysis in a Low-Current Gliding Arc Discharge

Yuan Tian, University of Mons, Ghent University

In this study, a low-current (25–75 mA) gliding arc discharge (GAD) system has been utilized for the synthesis of carbon-based materials. We investigate the effects of discharge current (I) and methane concentration (ΦCH_4) on the discharge features and carbon materials properties.
Two types of carbon nanomaterials are formed: graphene nanoflakes (GNFs), including single-layer, bilayer, and multilayer structures, predominantly synthesized at ΦCH_4 = 10%, and carbon nanoparticles (CNPs), primarily generated at higher ΦCH_4. For multilayer GNFs, two morphologies—“flat platelet” and “wrinkled layer”—are identified through Annular Dark-Field Scanning Transmission Electron Microscopy (ADF-STEM) images. For CNPs, a comparative thermogravimetric analysis (TGA) and derivative thermogravimetric (DTG) study with commercial carbon blacks (CBs) reveals that the thermal stability and purity of CNPs improves with increasing PD, shifting their properties closer to those of CBs.

Poster Session

PO011

Optimization of the reaction chamber of a microwave plasmalysis plant

Tanja Hasenjäger, Esslingen University, Germany

Despite the many advantages of microwave plasmalysis (MW) in CO_2 splitting, further improvements are needed to transfer the technology from laboratory scale to industrial scale. In this context, the conversion rate and energy efficiency are the most important parameters to be optimized. This study should contribute to a better understanding of the flow and plasma effects and thus improve the process. A simulation model will be developed that provides a simplified representation of the real reactor and enables reliable trends in terms of the flow pattern and conversion rate. This is followed by a parameter variation in the model with a focus on the inflow orientation and flow control in order to investigate their effects on the process. This is followed by an experimental validation in which the simulation results are compared with real measurement data.

PO012

CO_2 Conversion in an Atmospheric Plasma Reactor with Integrated Oxygen-conductive Membranes

Katharina Wiegers, IGVP, University of Stuttgart, Germany

Climate change and the goal of a closed carbon cycle necessitate the development of efficient CO_2 utilization technologies. A promising approach is the conversion of CO_2 in an atmospheric microwave plasma torch. Since industrial applications require CO as the sole product, selective oxygen removal is essential.
Oxygen-conducting ceramic membranes, such as $La_{0.6}Ca_{0.4}Co_{0.5}Fe_{0.5}O_3$, are being investigated for in-situ integration into the plasma process. These membranes exploit the thermal energy of the plasma effluent to enable oxygen permeation and achieve targeted separation.

Poster Session

PO013

Upscaling of the 2.45 GHz IGVP microwave plasma torch to 915 MHz

Andreas Schulz, IGVP, University of Stuttgart, Germany

Due to the essential fossil decarbonization, the chemical industry needs alternative carbon sources. CO_2 is a sufficient resource. If it is produced in unavoidable processes, such as cement production, its use is a valuable contribution to climate protection.
However, CO_2 can only be used as a resource for carbon chemistry if it is reduced to CO. CO can then be fed into Fischer-Tropsch synthesis to produce C-chemistry. In the 2.45 GHz IGVP microwave plasma torch, CO_2 can already be converted to CO with an energy efficiency of 40 %. However, the chemical synthesis industry requires such immense quantities of CO that upscaling the process is a basic requirement for meaningful utilization.
The poster paper presents initial results for the 915 MHz IGVP microwave plasma torch concept in comparison with the smaller 2.45 GHz system.

PO014

Electron beam-ionized plasma with self-biased electrode: towards catalytic conversion

David Johannes Schreuder, Technical University Dresden, Germany

Electron Beam (EB) sustained discharges are potentially a promising approach for the development of plasma catalytic processes, due to their capacity for independent control of electron temperature and electron density. In this study, we investigate the integration of EB-sustained discharges with metal electrodes electrically grounded through a resistor. The metal electrode acquires a self-bias potential because of charge injection from the EB (primary electrons) and the plasma (secondary electrons and ions). The magnitude of this self-bias potential can be regulated by appropriately selecting the resistance. This work summarizes the charge flow over steel and copper electrodes in direct contact with EB-generated plasma, with particular emphasis on the effects of the applied EB current and the resistance. The possibility to modulate the potential might offer a promising strategy to enhance plasma catalytic activity.

Poster Session

PO015

Towards an Electrical Model of Hybrid Discharge: Optimization of the Energy Delivery Network

Anthony Zschalig, Fraunhofer Institute for Electron Beam and Plasma Technology FEP, Germany

The novel concept of electron beam-assisted atmospheric pressure plasmas (hybrid plasmas) aims to overcome current limitations of non-thermal plasma-based synthesis processes. The successful implementation of this concept requires a detailed understanding of the underlying energy transfer mechanisms. However, no existing physical model sufficiently describes the complex interactions among the power supply, electron beam, and atmospheric pressure plasma. This poster introduces a conceptual model of pulsed hybrid plasma energy transfer in our process and highlights current efforts to optimize the Energy Delivery Network.

PO016

Plasma assisted decentralised biomethanol production

Ronny Brandenburg, Leibniz-Institute for Plasma Science and Technology (INP), Germany

The joint biogeniV project “Decentralized Biomethanol Production” combines research and development of new technologies for the utilization of biogenic CO_2 for the synthesis of biomethanol. It addresses unique solutions that can still be operated economically in small-scale biomass processing plants that are typical for the region of the alliance “biogeniV”, i.e. eastern Mecklenburg-Vorpommern with large structured farming and a low density of population. The results of this project should demonstrate the practical feasibility of plasma-assisted catalytic production of methanol from biogenic CO_2 and renewable hydrogen and also show plasma-chemical pathways for the conversion of biogas into synthesis gas. We present first results of CO_2 splitting in a gliding arc discharge as a preparation step for a catalytic methanol synthesis.

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