# BIENNIAL REPORT 2016/2017

LEIBNIZ-INSTITUT FÜR PLASMAFORSCHUNG UND TECHNOLOGIE E.V.

INP

FROM IDEA TO PROTOTYPE

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# BIENNIAL REPORT 2016/2017

## LEIBNIZ INSTITUTE FOR PLASMA SCIENCE AND TECHNOLOGY

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The Leibniz Institute for plasma science and technology is part of a strong research community that is one of the scientific pillars of our country. We prove our high degree of performance in an elaborate evaluation process, which is carried out every seven years, at the latest. The information provided by an independent commission of experts is used as an orientation basis for our work.

An important recommendation the experts gave upon the last evaluation in 2014 was to significantly increase the core funding of the institute in the field of plasma medicine. The state of Mecklenburg-West Pomerania and the German Federal Ministry of Education and Research in their capacities as donors of government grants followed these recommendations. We would like to thank the authorities for their trust in us as a future-oriented and efficient research facility. With these additional financial means we are now able to give highly qualified and committed employees a long-term professional perspective and thus expand our international top position in the field of Life Science.

In addition, we were able to improve the reputation of our research institute by two new professorships at Rostock University, which are the professorship W2 for surfaces, on the one hand, and the professorship W3 for high voltage and high power technology, on the other. This structural reinforcement of a long-term partnership will spur the positive development of the institute. Cooperation with excellent partners, generally is one of the pillars of our success. Both the new professorships in combination with the extensive laboratory areas in Rostock and the Diabetes Competence Centre Karlsburg, which we jointly operate with the Dr. Guth group of clinics have led to an expansion in our institute's portfolio. For example, a number of plasma medicine research laboratories have been directly established within the clinic since the initial plans in 2013 – this is an absolute novelty.

Within the globalised scientific landscape, international cooperations are mandatory. For example, the Applied Plasma Medicine Center (APMC) was opened in Seoul in February 2017. The project is jointly led and implemented by the Plasma Bioscience Research Institute (PBRC), Kwangwoon University in Seoul and us. This is the first time, one of the Leibniz institutions has become a partner in the Korean excellence research programme "Global Research Development Center" (GRDC). The clinic laboratories in Karlsburg and the application-oriented APMC are two more milestones in our attempts to successfully implement our research results in practice and to comply with our motto "From idea to prototype".

The present annual report contains many more scientific questions and issues that are resolved by the decisive contribution from the field of plasma technology. We hope you enjoy reading the report and will follow our developments through the next years.

**Prof. Dr. Klaus-Dieter Weltmann**
Chairman and Scientific Director

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## Plasma Physics Innovation Award

Great honour for two scientists from Greifswald: in July 2016 the Chairman of the Leibniz Institute for Plasma Science and Technology e.V. (INP), Prof. Dr. Klaus-Dieter Weltmann, and the head of the research department for plasma medicine, Prof. Dr. Thomas von Woedtke, of the European Physical Society in Leuven, Belgium, were awarded a prize for their pioneer work in the field of plasma medicine. Under the leadership of the two scientists, the teams were able to use the laboratory results to develop a completely new medical product – the kINPen® MED – within only a few years.
With this plasma pen it is possible to destroy pathogenic germs in wounds and to enhance wound healing. The kINPen® MED is used by a large number of clinics throughout Europe for treatment of patients.

The foundation for this innovation project was a strategic re-orientation of the institute. In 2006 the management board decided to pool the traditionally important research fields, such as plasma physics and medicine. Another aspect that set our course was the establishment of the world's first professorship for plasma medicine, which has been held held by the pharmacist Thomas von Woedtke since 2011. He was appointed to the University Medical Centre at Greifswald in cooperation with the INP. Above all, however, the long-term support by the German Federal Ministry for Education and Research, by the state government of Mecklenburg-West Pomerania and the City of Greifswald has made sure that an internationally leading centre for plasma medicine was able to develop in the far north-east of Germany. And we continue to expand our leading position: in future, the process is also going to be used in the areas of dermatology, dentistry and oncology. Initial studies have been successful.

## Chancellor Merkel visits the INP

High-ranking visitor: In August 2016, German Chancellor Dr. Angela Merkel (CDU) visited the institute. During a tour of the premises, the director of the institute Prof. Dr. Klaus-Dieter Weltman informed her about the plasma technologies developed there, which she considers to be among the world-leading technologies. During her visit, the leader of the German government and graduate physicist emphasised the interdisciplinary and application-oriented work of the facility, which ensures that innovations are transformed into viable business models as quickly as possible. One highlight of the tour of the premises was the department of plasma medicine research. The INP scientist Prof. Dr. Thomas von Woedtke demonstrated the functions of the plasma jet kINPen® MED. The pen has ensured a breakthrough in the treatment of chronic wounds and infectious skin diseases.


The motto of the institution – from idea to prototype – was also demonstrated to the official guest in other laboratories. Many research results are used in vehicle manufacturing, in the field of life science, in the energy industry and environmental engineering.

## Applied Plasma Medicine Center

From Greifswald to Seoul: A joint excellence research project by the Leibniz Institute for Plasma Science and Technology and the Plasma Bioscience Research Institute in Seoul was initiated in November 2016. The Korean government supports the establishment of an “Applied Plasma Medicine Center” with a sum of 3.4 million Euro. Consequently, this is the first time that one of the Leibniz institutes has been included in the “Global Research Development Center”, a highly prestigious Korean science programme. The scientists and researchers of both sites intend to establish the application of cold plasma in the Asian region. Their goals are to compile a list of joint performance parameters and to prepare various clinical studies. The official opening of the laboratories in Seoul was in February 2017.

## New junior research groups

New work group: The German government continues to support the fundamental research performed at the Centre for Innovation Competence (ZIK) plasmatis providing a large support sum. Thanks to these funds, in January 2006 it was possible to introduce a new work group of six scientists, who will do research in the field of effects of cellular redox processes due to cold plasma. Since January 2017, the scientists have also been performing research in the field of plasma-liquid interaction. The overall sum provided by the German Ministry for Education and Research for another five years is 9.7 million Euro. The state-of-the-art ZIK laboratories employ biochemists, pharmacists, biologists and physicists who work together in the field of plasma medicine under one roof, which is unique worldwide. A major topic is the aspect of wound healing; moreover, the new junior research teams analyse implementation of the previously gained insights in other fields of application. In this context, the focus is on the effects of cold physical plasma on tumour cells.

## 25 years of INP

A quarter of a century of top-level research: In June 2017 a milestone in the history of the Leibniz Institute of Plasma Science and Technology was celebrated by an official ceremony. In the presence of more than 200 guests, including employees, sponsors and partners, Prof. Dr. Klaus-Dieter Weltmann took stock of the absolutely positive development of the institute since its foundation in 1992. At that point, the name of the facility was Institute for Low-Temperature Plasma Physics. Seven years later, the scientists and researchers moved to a new building with 3,700 square meters of laboratory and office area. In his speech Weltmann acknowledged that Greifswald could no longer be imagined without plasma research. Thomas Rachel (CDU), State Secretary for Science and Research, described the institute as a "scientific hot spot" that is well established within the international research landscape. The State Minister for Education and Science, Birgit Hesse (SPD), mentioned the extraordinary research performance. The Centre for Innovation Competence (ZIK) plasmatis founded in 2008 has evolved to an internationally leading site for plasma medicine. Another important milestone was the opening of the Arc Research Laboratory in 2015.

## TOTAL E-QUALITY distinction

Proactive compliance with equal opportunities policy: In October 2017, the Leibniz Institute for Plasma Science and Technology was honoured for their equal opportunities policy and the family-friendly working conditions for the second time. The TOTAL E-QUALITY Deutschland e.V. association repeatedly confirmed the successful and sustainable commitment of the research institute in terms of equal professional opportunities for men and women, particularly for the management levels. The award initiated by the German government was handed out to the Gender Equality Officer of the Greifswald institute, Dr. Christine Zädow in Gelsenkirchen. The distinction will be valid for three years. In 2020 the facility plans to apply again for the award. www.total-e-quality.de


## CarMON: nano particles for energy accumulators

Batteries of the future: Together with partners in Saarbrücken and Düsseldorf, we at Greifswald perform research on production of nano-materials for energy accumulators. The CarMON (New Carbon-Metal Oxide Nanohybrids for Efficient Energy Storage and Water Desalination) project was started in 2017 and is sponsored by the Leibniz Association with an overall sum of 1.3 million Euro. In the first step, the focus is on precisely controlling and reproducing these tiny particles. Only if this prerequisite is met, economic use is possible. The project management is held by the INP scientist, Dr. Angela Kruth. She has already been working with plasma processes that are capable of generating nano-layers for fuel cells or solar energy plants. Other fields of application are in the areas of precision-optics and semi-conductor technology.

## Professorships in Rostock

Academic career: Two scientists from the Leibniz Institute for Plasma Science and Technology were appointed professors at the Rostock University in 2017. The deputy scientific director of the INP, Dr. Dirk Uhrlandt, was granted the professorship for "High voltage and high power technology" at the Institute for Electrical Power Engineering at the beginning of the year. The physicist was previously lecturing at the St. Petersburg Polytechnic University in his capacity as guest professor. Uhrlandt has been employed at the INP since its foundation and has been responsible for a number of major research projects. In September 2017, Dr. Ronny Brandenburg received an certificate of appointment by the State of Mecklenburg-West Pomerania. He teaches the subject of "Plasmas for surfaces" at the Faculty of Mathematics and Natural Sciences and is head of the INP research department of "Plasma Chemical Processes".

Photo of the construction of the future centre for Life Science and Plasma Technology (C4LP) in Greifswald. Completion is planned for 2019.

# Outlook

The Leibniz Institute for Plasma Science and Technology e.V. has proved the great economic potentials of plasma technologies in a vast number of projects. In many cases our employees work in close cooperation with representatives from the industry. The examples below provide an outlook on our projects in the near future.

## Centre for Life Science and Plasma Technology

A place for innovations: From the middle of 2018 the Centre for Life Science and Plasma Technology is going to be built in the direct vicinity of the Leibniz Institute for Plasma Science and Technology e.V. (INP), which will be used as a new research and foundation centre with international mass appeal. The new building will provide many more opportunities for cooperation with the industry and developing prototypes for the market. Therefore, the INP will rent a production hall with a height of eight metres, a large number of offices and special laboratories.

Overall, the Hanseatic City of Greifswald will invest around 32 million Euro in the new building. It is the largest project the municipality ever planned. Half of this investment sum is provided by the state through support funds. The opening is planned for 2019. 240 new jobs will be created in the new complex, and we want to contribute to that. This project holds additional capacities for new companies, for implementing research results in products, said State Minister for Economy, Harry Glawe (CDU), when issuing the subsidies grant. We at the INP hope for new impulses for plasma science at our main site, particularly in the field of bio-economics.

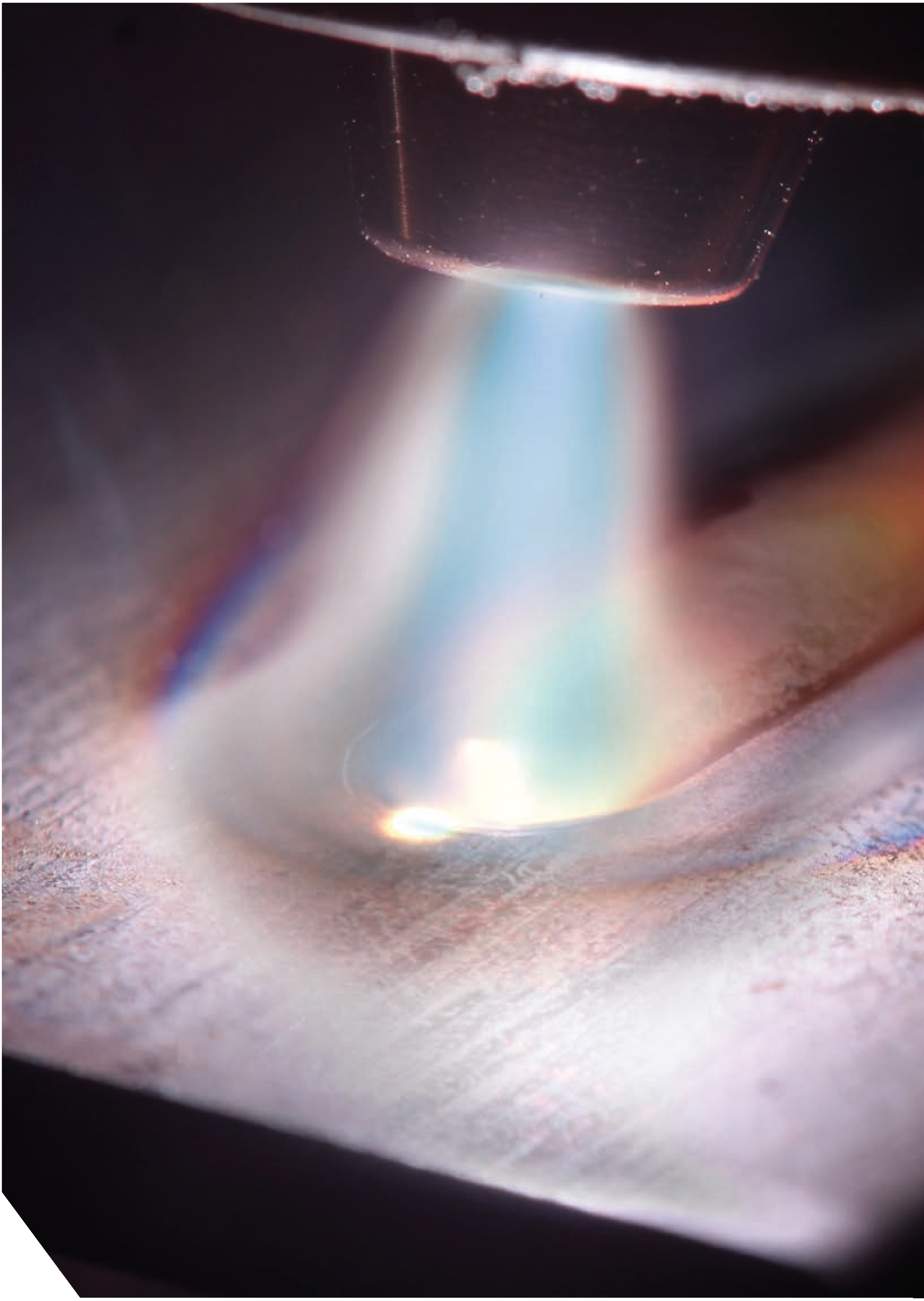
## Plasma in agriculture

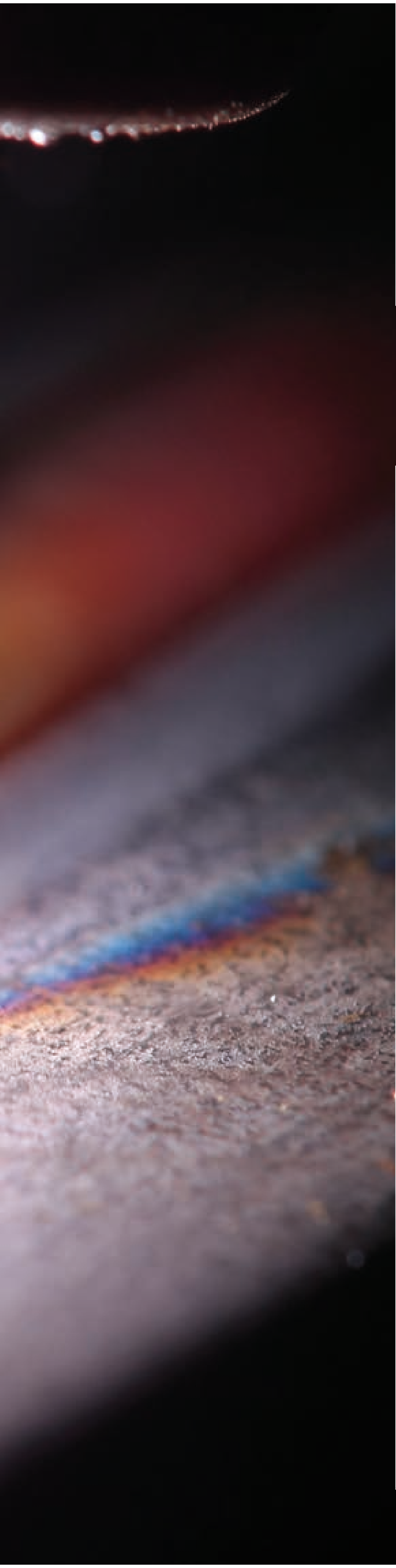
Resistant seed grains: The Leibniz Institute for Plasma Science and Technology includes a new, economically important field of application for cold plasma into its portfolio, i.e. agriculture. The two biologists, Henrike Brust and Nicola Wannicke, as well as their colleagues, the physicist, Stefan Horn and the technician, Michael Timm, have analysed the methods for increasing the germination capacity and resistance of seeds since July 2017.

This research project focuses on grain types, such as wheat and barley but also on species from the legume family, such as red clover and alfalfa. In cooperation with the Leibniz Institute for Plant Genetics and Crop Science the seeds treated with plasma sources are going to be tested on testing grounds. The goal is to reduce the use of chemicals on fields and to protect the crops from plant diseases in a gentle manner. So far, the seeds have been treated with seed dressing.

First, the quartet of scientists applied for a grant of funds from the sponsor scheme “Wandel durch Innovation in der Region” (Change through innovation in the region) by the Federal Ministry of Education and Research. Together with the Neubrandenburg University of Applied Sciences a future-oriented strategic concept will be developed from April 2018. At the same time, a new, specially equipped lab is being built.

Within the industry, plasma has long been considered a key technology. But there is still a great amount of research work to be done in order to achieve breakthroughs in other fields of application.





# RESEARCH DIVISION

# MATERIALS & ENERGY

## Overview

This research department combines technological plasma-related topics in the fields of energy and production engineering. Current fields of application are production of functional surfaces, thin layers and catalytically active materials by means of plasma processes, also plasma chemical synthesis and use of electric arcs in electrical energy technology and process engineering.

The focus particularly is on the technical challenges of the energy revolution. For example, research is done on new materials for battery technology, photovoltaics, as well as synthesis and storage of hydrogen. In addition, work concentrates on increasing the performance and reliability of the energy infrastructure by means of new components. Currently, the scientists analyse how to treat surfaces using non-thermal plasma at atmospheric pressure. Another research topic is interaction of thermal plasma with electrodes and walls. Also, development of measuring methods for various applications, ranging from vacuum processes to electric arc welding, is a priority of the research work. Only in this way, the analysis of underlying physical and chemical processes is possible.

## Research Programme Materials and Surfaces

- Functional layers and coatings
- Nano structuring of SO2-sensitive electrode layers

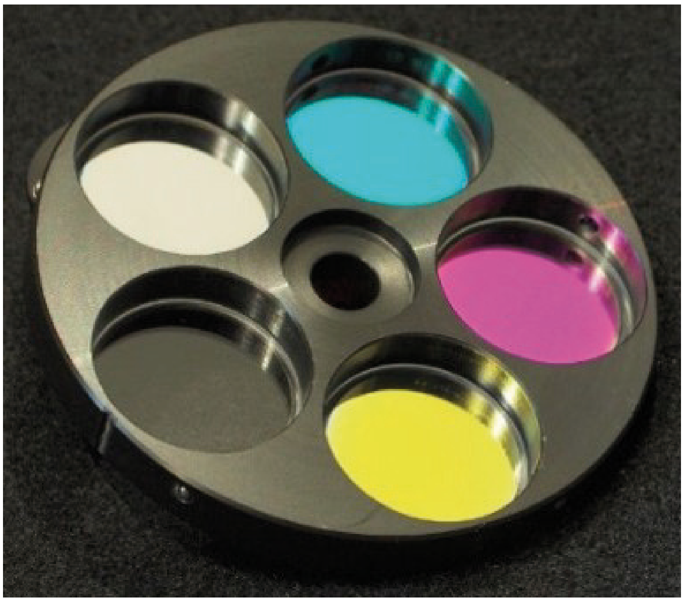
## Research Programme Plasma Chemical Processes

- Plasma monitoring and plasma chemical processes
- Plasma chemistry
- Kinetics of transient molecules in plasma

## Research Programme Welding and Switching

- Electric arcs
- Analysis and modelling of switching arcs using spectroscopic methods

# Overview



Optical thin-film interference filters prepared at INP Greifswald using ion assisted plasma processes.

Today plasmas are indispensable tools in the field of thin-film technology. They create new surface properties and enable synthesis of nano-scale materials. The spectrum of plasma-assisted and ion-assisted surface treatment processes ranges from structured material removal, such as etching or precision cleaning, to modification of the interfacial properties, e.g. for control of gluability or printability, and extends to production of functional films with applications for protection against corrosion, heat or mechanical abrasion, and for the coating of optics.

Synthesis of nanostructured materials or nanoparticles using plasma processes opens up new perspectives in the area of storage and transformation of renewable energy sources, such as components for electro-catalysis (battery and fuel cell technology) or hydrogen technology. The variety of applications is based on a number of engineering advantages offered by plasma processes, such as a low thermal load of components, comparative environmental compatibility, precise control, along with negligible impact on the properties of the base material.

In the research programme, innovative plasma processes are studied, technical plasmas are applied, experimentally characterized, simulated and considered in context with film and surface properties. Knowledge of this correlation ultimately results in better controled manufacturing processes, which in turn leads to superior products.

## Fields of application

### Materials for renewable energies and catalytic processes

Critical components and materials for the storage and conversion of energy can be produced using plasma-assisted methods. For instance, catalytically active surfaces for hydrogen technologies or for batteries can be synthesized but also components and materials for interrelated areas, such as sensor technology, chemical synthesis or water and gas remediation processes.

### Functional coatings

The surface properties of materials can be enhanced by thin coatings. These coatings serve specific functions, depending on the application: they reduce abrasion and friction of mechanically stressed parts or protect metals against corrosion. They enhance the gluability of material combinations, promote a decorative appearance, reduce the permeation of gases through materials or improve the scratch resistance of plastics. In semiconductor fabrication and optics, coatings operate as dielectric material, EMC shielding or anti-reflective layers.

### Optical coatings

Plasma- and ion-assisted processes represent well-proven methods to produce high-quality thin film optics. These are key components for optical equipment in the areas telecommunication, imaging, laser applications, or measurement technology. The performance of many optical components, such as highly-reflective dielectric laser mirrors filters or high-quality optical filters is mainly based on interference coatings that are grown on the surface of optical elements. Moreover, properties of optical elements can be controlled by structuring their surfaces at nanoscale, e.g. to produce anti-reflective coatings.

# Application-oriented outlook

With regard to the synthesis of materials with relevance for renewable energies and catalytic processes, the research programme will engage in plasma-assisted synthesis techniques for the deposition of nanostructured metallic, metal-organic and graphitic particles and thin films and their characterisation. Magnetron sputtering, plasma-ion-assisted deposition, plasma pyrolysis and PE-CVD are deployed as deposition methods.

In the framework of the collaborative research project CarMON, which started in January 2017, the plasma-assisted formation of carbon/metal-oxidic nanohybrid materials is investigated. These nanohybrides represent important key materials for energy storage in batteries and supercapacitors, but also for electrochemical desalination. The project uncovers fundamental correlations between the nanostructures and the plasma properties prevailing in the process, with the aim to affect precisely the electrochemical electrode properties already during their manufacturing. Thus, the project develops pre-requisites for the production of highly efficient electrode materials at industrial scale.

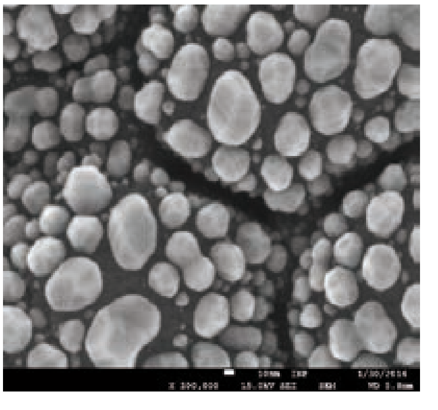
With the growth of carbon nanostructures, and furthermore, of metal-oxidic and metallic nanoparticles using atmospheric plasma-in-liquids processes, we will brake new ground.

A number of application oriented projects will start in the near future to develop synthesis methods for Pt- and Ni-based catalysts, for electrode- and membrane components composed of graphene or metal oxides and to affix catalysts to substrates.

The collaborative research project PlasFaser pursues a novel approach for the fabrication of optical fibers for high power fiber lasers. Dopant material is deposited on quartz glass preforms using atmospheric pressure microwave plasmas as a prerequisite for a future production of glass fibers with unrivalled quality. Plasma diagnostics, coupled with simulation and modelling are implemented to gain a better insight into the chemical and physical processes prevalent in the plasma. In consequence, optimized process settings form the basis for the production of novel glass material at the collaborating institute IPHT.

The collaborative research project PluTO+ is dedicated to the in-situ monitoring of plasma parameters in industrial PIAD production facilities. PIAD represents a process for the fabrication of high-quality elements for interference optics in areas such as laser applications or telecommunication. For the first time, quantitative information on the plasma properties present during the deposition of $TiO_2$, $SiO_2$, $Al_2O_3$ und $MgF_2$ coatings could be obtained by experiment and simulation and put into relation to the resulting thin film properties. This fundamental understanding allows to establish a new quality of control algorithms which are based on the plasma parameters directly relevant for thin film growth. Building on these advances, further efforts in close cooperation with partners from industry will concentrate on the evaluation of the potential of these novel concepts and for their commercialization regarding the production of interference optics.

The evolution of PIAD processes thus alleviates the compliance of product demands such as reproducibility, spatial homogeneity, improved energy efficiency and enhanced deposition rate without compromising the quality of the coatings.



Nano-composite film on the topic Materials for energy storage and -conversion deposited at INP Greifswald using PVD. The typical particle sizes are appproximately a few 10 nm.

# Core funded project Functional Coatings

The spatio-temporal characteristics of a non-thermal atmospheric pressure plasma jet (ntAPPJ) is investigated along with its impact on the reactive deposition of functional coatings by PE-CVD (Plasma Enhanced Chemical Vapour Deposition) processes. The particular ntAPPJ is distinguished by the non-linear effect of filament formation. The resulting gas dynamics is the decisive factor for observed superior reproducibility of the conditions and the properties of the deposited coatings.

It was found that the gas dynamics can trigger a self-organization of the discharge filaments the so-called locked mode (LM). When operated at LM, the filaments form a regular, symmetric pattern, which, as a whole, rotates with a controllable azimuthal velocity (fig.). This property is beneficial and a prerequisite for a thorough mixing of the thin-film forming precursor vapours (HMDSO, Hexamethyldisiloxane or OMCTS, Octamethyltetrasiloxane) in the reactive zone of the ntAPPJ, which eventually leads to an enhanced quality of the coatings (e.g. carbon free coatings).

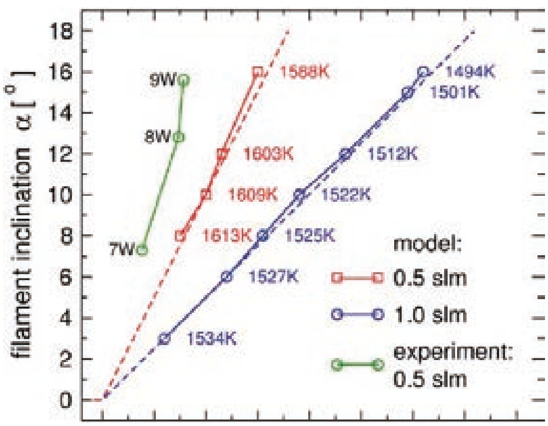
The investigations were expanded towards the compound Tetrakis(trimethylsilyloxy)silane (TTMS) and the results were compared with experiments using a complementary plasma source (MW-Jet, 2.45 GHz, J. Schäfer et al., Surf. Coat. Technol. 295 (2016) 112–118). Using this source, a nanodendritic silicon dioxide structure with extremely enlarged inner surface could be created.

An alternative thin film deposition technique (LA-PECVD, liquid-assisted PECVD) was studied to decipher effect of different precursors (HMDSO, OMCTS, TTMS) on the chemical composition of the deposited coatings (J. Schäfer et al., Thin Solid Films 630 (2017) 71–78). The deposition rate could be significantly enhanced to values of 28 nm/s using LA-PECVD and TTMS.

A classification of the chemical composition of the films could be conducted, based on the comlex film and surface analysis using XPS (X-ray Photoelectron Spectroscopy), FT-IR-Spectroscopy (Fourier Transform Infra Red) und EDX-Spectroscopy (Energy Dispersive X-ray Photon Spectroscopy).

The modelling of the ntAPPJ provides profound insight into the dynamics of the film deposition process. A two-dimensional hydrodynamic model is characterizing gas flow, heat balance, plasma formation, and reactive kinetics of the precursor molecules (F. Sigeneger et al, Plasma Process Polym. 2017, 14, 1600112). The plausibility of the model is bolstered by consistent temperature measurements using LSD (Laser-Schlieren-Deflectometry).

A 3-dimensional model of gas flow and energy balance has been introduced. This model comprises the previous experimental and theoretical results (J. Schäfer et al, Plasma Phys. Control. Fusion 60 (2018) 014038). Part of the investigations were funded by DFG (DFG-Cluster Ogaplas and TRR-24 Complex Plasmas).




Linear dependence between inclination angle of filaments and their rotational frequency during Locked Mode for varied operation conditions (J. Schäfer et al, Plasma Phys. Control. Fusion 60 (2018) 014038).

# Third party funded project
# Nanostructuring of $SO_2$ sensitive electrode films

The usage of In-situ $SO_2$ sensors is gaining increasingly importance for the combustion management in large combustion plants or in biogas plants. A high $SO_2$ concentration along with low $O_2$ content in the combustion chamber leads to a reducing atmosphere on all exposed hot steel parts (e.g. finned walls). Metal-sulphur compounds are formed which have a detrimental effect on the material strength. Moreover, the combustion of non-desulphurized heavy oil which amounts to appr. 100.000 ships wordwide poses a massive environmental impact.

The well-known and frequently processed sensor arrays, which consist of a multitude of different sensors with different sensitivities towards the particular gas type are not suited for elevated temperatures in real flue gas applications, neither regarding the temperature range nor the sensor material.

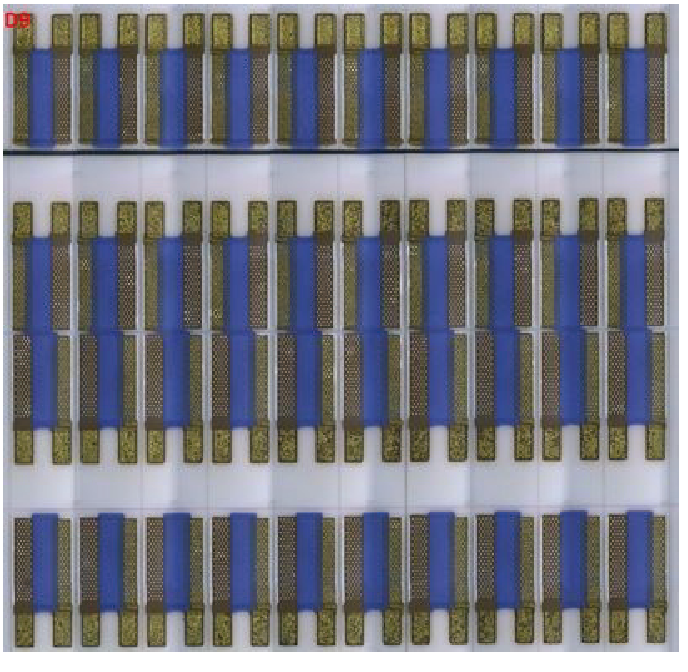
Therefore, the project is aimed to a miniaturized design of an in-situ sensor based on nanostructured, coated and so far non-available electrode materials. Using multivariate data analysis and adaptive online optimization the sensor is integrated into a complete measuring device.

In a two-step synthesis $SO_2$ sensitive electrodes were created on $O_2$-ion-conducting solid electrolyte films. In a first step, amorphous or semi-crystalline ceramic / metallic composite films were deposited using a co-sputtering process. In a following step, the material was tempered to initiate oxidation and re-crystallization.

Thanks to the defined porosity of the synthesized ceramic coatings gas molecules can penetrate from within the gas department to the three-phase boundary thus allowing an adequate gas exchange at the electrodes.

Compared to conventional production processes, such as e.g. silkscreen printing or manual application, the plasma-assisted process is far more precise for film thicknesses in the range between 100 and 500 nm.

The signals obtained from Au/$TiO_2$ electrodes produced using a plasma-assisted process show a distinct and stable dependence on the $SO_2$ concentration for values up to 0.1 vol.%. A negligible temperature shift and a stable zero-point at 2.1 vol.% $O_2$ and 10 vol.% $H_2O$ represent further advantages of the new sensors. The visibility of lucid crystals indicates the presence of $TiO_2$ after combined deposition and after oxidative tempering at 400 °C in air.




Practical design of a sensor array

## CONTACT

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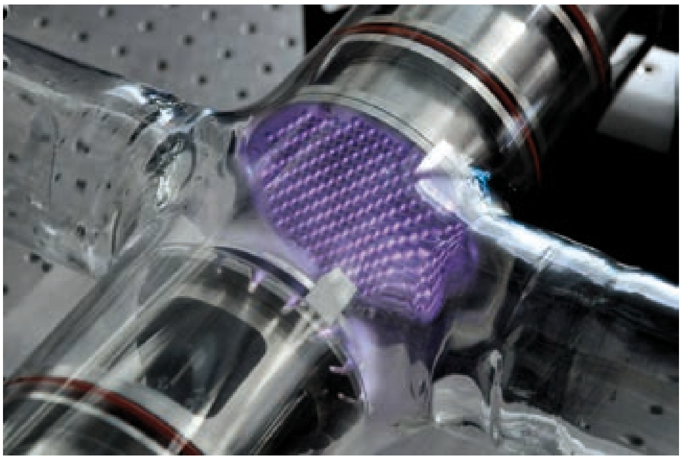
# Overview



View into one of the research reactors for the study of plasma chemical processes during plasma-nitriding (image from the INP website)

The research topic of "Plasma Chemical Processes" focusses on the physics and chemistry of reactive plasma. The team develops approaches and methods for control of plasma chemical processes. This particularly also includes the determination of concentrations of charged and uncharged plasma species, their energy distribution, as well as the analysis of emissions by the plasma and the interaction of plasma with the adjacent surfaces. For this purpose, state-of-the-art infrared absorption spectroscopy methods are available, which represent a highly sensitive and accurate way for (in situ) determining molecule concentrations in plasmas and which are also capable of measuring the plasma kinetics. For examination of the processes during electric breakdown and morphology of plasmas, fast spectroscopic or imaging methods are used.

The diagnostic work is supplemented by modelling and is performed in close cooperation with partners from science and industry. Its priority is the development of new methods for the control of plasmas in surface treatment or plasma chemical synthesis.

## Fields of application

Process control in industrial plasma processes: Reactive plasma is one of the most important tools in the industry. It is used for activation, cleaning, coating and etching, among others. However, empirical definition of process parameters is increasingly reaching its limits and a need for methods for determining plasma parameters and its composition has arisen. The IR absorption spectroscopy developed by the plasma chemical processes research team, uses quantum cascade lasers. This is one of the most sensitive and most accurate methods for chemical plasma analysis.

Identification and quantification of important plasma parameters in atmospheric pressure plasmas:
Atmospheric pressure plasma became more and more important in research and for industrial use. Several new fields of application, such as plasma synthesis, plasma medicine or decontamination started within the last decade. Our processes for imaging and spectroscopic studies enable the analysis of the electrical breakdown and to provide the determination of plasma parameters. In addition, the measurement of reactive and stable species concentrations is possible by cavity-enhanced absorption spectroscopy. Application of the specified processes ensures important contribution to the interpretation and the control of existing or new atmospheric pressure plasma sources.

Plasma nitriding:
The plasma-nitriding process is one of the most important processes to increase surface hardness of workpieces toprevent abrasion, adhesion and corrosion. Together with the Bergakademie Freiberg Technical University, INP has developed an improved process ("active screen plasma nitriding") that eliminates arc formation or other boundary effects. Thus, it ensures more uniform processing of the workpieces.

Trace gas detection:
Identification and verification of gases in very low concentration levels at great accuracy are important in medicine, environment protection, safety engineering and many other fields. Analysis of trace gases by combining modern infrared laser light sources and optical resonators allows for determination of gases down to ppt range.

# Plasma monitoring and plasma chemical processes

Due to the fact that manufacturing technologies become more and more complex so that they can no longer be appropriately optimised by means of empirical determination of process parameters and statistical modification we assume a great application potential for the future use of mid wavelength infrared radiation (MIR) absorption spectroscopy with quantum cascade lasers. In combination with plasma simulation we are able to demonstrate optimisation potentials and to clarify processes.

By concentration measurements of key species or unwanted contamination and thus, increased understanding of the processes, plasma processes are developed in a more targeted and optimised manner. Processes that provide great stability and a high degree of reproducibility, as well as low material reject rates and short processing times are made possible.

CELISE prototype for trace gas detection (currently being developed)

Despite the unique features of this method (great variety of detectable plasma species in stimulated or basic condition; great sensitivity) its implementation in commercial plasma reactors, e.g. in semi-conductor production, is very elaborate and complex from the technical point of view. In this context, we have established concrete projects with partners to develop appropriate solutions.

Within the scope of the transfer project SAW VIP-USD Transfer funded by the Leibniz Association, the economic application of the quantum cascade laser MIR cavity enhanced absorption spectroscopy (QCL-MIR-CEAS) is promoted. The development of the prototype of a compact, portable, ultra-sensitive (ppt sensitivity) multi-component trace gas sensor has established a new class for research and industry. The prototype is designed for the application field of trace gas detection. The application options include, e.g. monitoring of technical processes, monitoring of pollutants' emission, breathing gas analysis and detection of hazardous substances. What is more, the combination of modern infrared laser light sources and optical resonators for an increase in sensitivity will also be interesting for other industrial areas.

In addition to examination of the chemical processes, their correlation with physical processes during ignition and development of plasma is a key for design and optimisation of plasma processes. The understanding of the phenomena in electrical breakdown but also the role of the surface processes both in formation of plasma and the subsequent plasma chemistry represents a great challenge particularly for the atmospheric pressure plasma sources and processes. Ultrafast electrical measurements, imaging processes and spectroscopic methods with great sensitivity (e.g. time-correlated single photon counting) make it possible to understand these phenomena and take them into account for the design of new plasma reactors and processes.

Plasma offers a special opportunity for generating short-lived (reactive) chemical substances efficiently and on-site (on-demand) by means of electrical energy. An example for this is generation of ozone from ambient air oxygen. Future projects are intended to develop this potential further and to identify new solution methods for both the industry and society.

# Core-funded project Plasma Chemistry

Structure of the first frequency comb for absorption-spectroscopy analyses of plasma world-wide at INP (cooperation with Torun University, Poland)

The research programme "Plasma Chemical Processes" was newly founded at the INP in 2017 and is based on the former research programme "Plasma Monitoring". Within the scope of the core-funded project of "Plasma Chemistry" new diagnostic methods were developed for the detection of radicals and stable species and used on various plasma sources and processes.

In cooperation with the University of Oxford it was possible for the first time to detect the hydroperoxyl radical in the effluent of a plasma jet in argon with admixtures of water at atmospheric pressure and to examine its properties using the method of "Optical Feedback Cavity-Enhanced Absorption Spectroscopy (OF-CEAS). The measured concentrations of the radical was maximum 1-3 ppm. It depends on the amount of added water vapour to the argon carrier gas. The OF-CEAS method provides the required sensitivity to identify densities of transient species in plasmas of only a few millimetres in width. Other radicals that have been intensely examined in previous periods are the silyl radical (SiH3) and the methyl radical (CH3). Both radicals play a major role in many coating processes (PECVD). For the silyl radical, additional work is performed in terms of experimental determination of its line thicknesses in the MIR region.

A frequency comb-based laser absorption spectroscopy unit was set up as a new diagnostics method. Optical frequency comb systems (FCs) on the basis of fibre-coupled femto-second lasers are excellently suitable for spectroscopy applications: due to their robust and compact design they replace many 10,000 of individual lasers. The instantaneous spectrum of a frequency comb consists of a large number of equidistant laser lines with precisely defined frequency spacing, which correspond to the pulse repetition rates. The typical spectral band width is a few 100 of nm and thus effortlessly allows for simultaneous capturing of several species within the plasma. With this project, the institute is able to assume a pioneering role, particularly for molecule spectroscopy applications based on FC systems.

The FC used at INP has a repetition rate of 250 MHz and emits at 3.2 µm (2900 – 350 cm-1), which is the range where many hydrocarbons absorb. The first-time use of a state-of-the-art FC is intended as a new approach for clarification of plasma-surface interactions. FCs are intended to be used in wide-band frequency comb spectroscopy (CE-DFCS). The method of CE-DFCS will allow for the simultaneous detection of a large group of transient reaction partners in direct proximity of the surface. Due to the achievable time-resolution in the µs range, comprehensive new information on the reactants' kinetics will be possible. The goal of simultaneous monitoring of the plasma sheath and the substrate surface based on the high sensitivity and time-resolution provided by CE-DFCS is to obtain basic new insights into the physical and chemical processes in this interface, which are important for both fundamental research and for technological applications.

# Externally funded project on kinetics of transient molecules in plasma

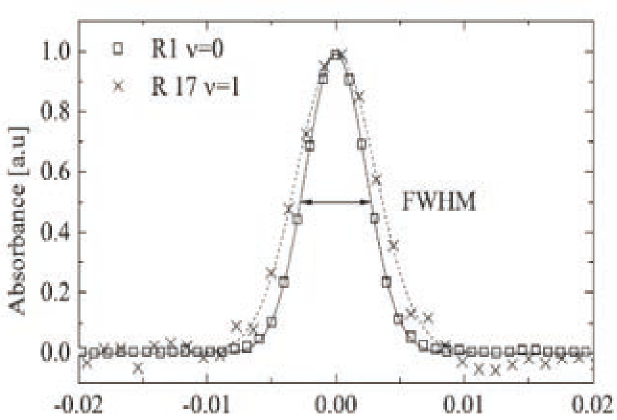
The sub-project B2 on "kinetics of transient molecules in plasma" within the framework of the DFG-funded collaborative research center TransRegio24 "fundamentals of complex plasma" Greifswald-Kiel was devoted to the basics of the kinetic behaviour of transient species in non-equilibrium plasmas and their interaction with adjacent surfaces. The main focus was on non-stationary plasma, such as microwave or radio frequency discharge at lowand atmospheric pressure. Resonator-based spectroscopy was used and later combined with technologies working with evanescent waves.

Analyses included, among others, the plasma chemistry of RF discharge with aluminium isopropoxide (AIP) as a metal-organic precursor for the deposition of metal oxide layers, the kinetics of NO formation in pulsed DC low-pressure discharges in nitrogen-oxygen gasmixtures, the composition of microwave plasmas for large-area deposition of nano-crystalline diamond layers, and chemical conversion and fragmentation of HMDSO as a precursor for the deposition of silicon oxide layers.

The densities of nitrogen monoxide, nitrogen dioxide, and nitrous gas could be measured in different gas compositions in DC low-pressure discharge in a time-resolution manner using quantum cascade laser absorption spectroscopy. In combination with simulation, deep insights could be gained on plasma chemistry by inclusion of 95 different species.

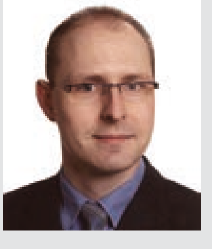
The methods of laser absorption spectroscopy and optical emission spectroscopy were combined for the purpose of quantitative determination of the gas temperature and the concentration of seven species (including the methyl radical) in low-pressure microwave plasmas in a gas mixture consisting of hydrogen, methane and carbon dioxide. Dissociation and fragmentation of the precursors, as well as the subsequent chemical processes could be clarified.

As is shown in the figure below, the narrow line width of the external cavity quantum cascade laser (in cooperation with LSPM-CNRS Villetaneuse, France) allows for exact measurements of the absorption line profile for different oscillation level of the carbon monoxide molecule. The broadening of the lines caused by the Doppler effect, can be described by a Gaussian function, whose free width half mean is a measure for the temperature of the absorbing specie.




Absorption measurements at the CO molecule in microwave plasmas in hydrogen, methane and carbon dioxide at 0.35 mbar and 3 kW. By means of the free width half mean (FWHM) of the absorption characteristics, the temperature of differently excited oscillation level of the molecule can be determined.

## CONTACT



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# Overview

The research program Welding and Switching focuses on thermal plasmas, in particular, electric arcs and their technological applications, as well as studies of discharge phenomena in high-voltage components of electrical networks. The highly varied application potentials of  arc plasmas are in joining, cutting technologies and in metal processing. The work of this research program team addresses  arc welding processes, like e.g.  tungsten inert gas welding and metal active gas welding. Currently, investigations are also performed of submerged arc welding processes. Furthermore, work is performed on laser welding and laser-supported electric arc welding.

Research work on switching systems in electrical engineering is focussed on discharge phenomena (e.g. switching arcs in circuit breakers for all voltage levels. This particularly includes vacuum switches and SF6-free gas circuit breakers for medium and high-voltage levels. Study of ageing phenomena in high-voltage components due to partial discharges support the condition evaluation and lifetime prognoses, as well as service intervals.

Despite long-term research work, detailed knowledge of physical mechanisms in the electric arc and the interaction between arc plasmas and the surrounding materials (walls, electrodes) is still lacking.

Together with modelling and simulation, development of optical diagnostic methods for thermal plasmas is an important research instrument. Pyrometry of surfaces, imaging emission and absorption spectroscopy and high-speed cinematography are used together with electrical measurements for quantitative analysis. By combination of various diagnostic methods, space- and time-dependent plasma parameters, such as temperature, composition, pressure, and flow velocity, becomes available. The values obtained through experiments are used for reaching a deeper understanding of the processes, on the one hand, and for validation of simulations, on the other hand. In the field of modelling and simulation, the work mainly targets electric arc models based on a magneto-hydrodynamic approach (solution of Navier-Stokes equations in combination with electro-magnetic equations). Currently, new models which avoid  assumptions of the local thermo-dynamic equilibrium are developed. These models allow for a significantly more exact description of near-electrode plasma regions and the arc-electrode interaction. Further work is performed on radiation transport and on material data, also for plasmas in thermal non-equilibrium.

Detailed knowledge of the properties of electric arcs and the adjacent regions, especially electrodes, and of the  arc control promote the development of new approaches for improvement of existing apparatus concepts and processing. This ranges from the urgently required increase in performance and reliability of electrical components within the scope of the energy revolution to qualification of joining and application processes for Industry 4.0 to support the generative production processes.

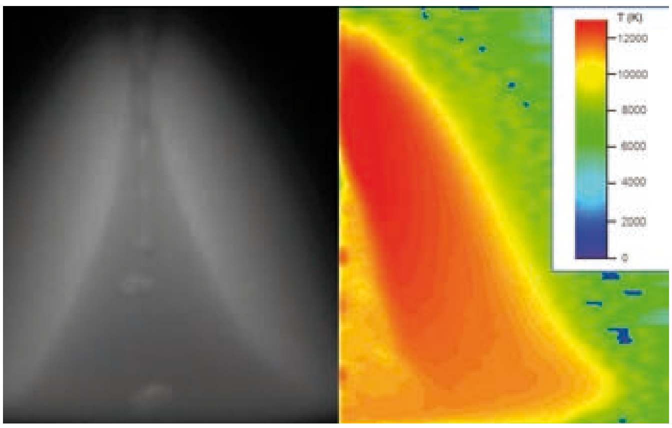



Image from a high-speed video (LH) and a temperature profile (RH) for a metal active gas-welding process. The droplet transfer is visible on the axis.

# Application-driven outlook

Setup for optical analysis of a submerged arc welding process for joining of high-strength steels.

In addition to the behaviour and properties of the welding arc plasma, the weld pool, in particular for gas-metal arc welding, the processes taking place in and at wire surface and the material transfer phenomena are under investigations. Knowledge about the influence of the shielding gas used as well as of the process parameters on these processes are indispensable for the adaptation of new process types (especially high-performance processes or processes with minimal energy input) and for the adjustment to new materials, such as high-alloyed steels used in thin sheet metals.

In addition to development of application notes, handling and control of the processes, and ultimately, increase of process safety is in the foreground. Application and further development of spectroscopic diagnostics ensures deduction of easy-to-handle sensor concepts, for example, based on photodiodes. Spectral filtering of optical signals in many cases ensures a more sensitive control of process instabilities in comparison to evaluation of electric signals.

Furthermore, the information on reduction of emissions, such as welding fumes, may be obtained. The combination of electrical and optical signal evaluation provides significant potential for process control, process regulation, and quality control in arc-based technologies for metal processing.

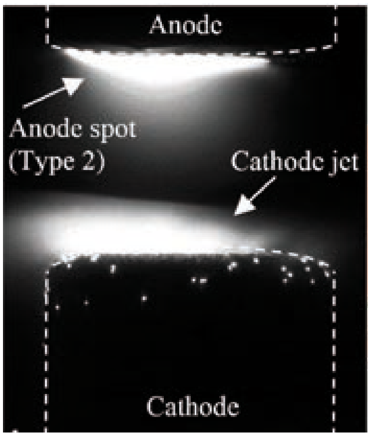
The research work on circuit breakers includes simulation of processes in real-type switches within the scope of experimental setups and model switches with optical access. This ensures application of spectroscopic diagnostics as one of the few options for experimental determination of physical properties of the switching arc. In this field, the position of the INP is unique and the institute currently uses its status to study the radiation properties of the arc, the erosion behaviour of the electrodes and the evaporation of chamber and nozzle materials. These insights are indispensable for the development of concepts for environmentally compatible circuit breakers, among others, that avoid the use of the climate-harmful switching medium, like e.g. SF6. At the same time, information on the use of new chamber materials is obtained, that may contribute to increase of the switching capacity, the lifetime and the reliability, as well as reduction of the size of the devices. Investigations on the increase of the switching capacity also include future concepts for direct current switching of . These are of current significance for the introduction of high-voltage direct current transmission (HVDCT) for adjustment of the transmission networks to the requirements of the energy revolution.

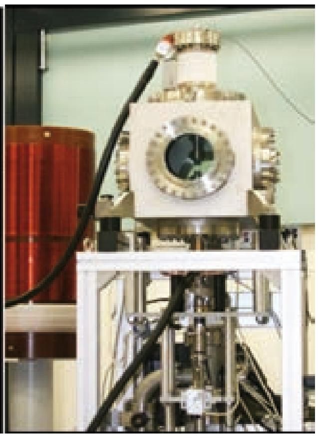
A trend in industrial research and development of circuit breakers is the introduction of simulation-supported design, also for considerable reduction of the development costs. For this purpose, complex magneto-dynamic simulation concepts are required. The work of the INP addresses this trend, particularly by electric arc simulations and modelling of the near-electrode regions. Furthermore, the plasma and surface properties determined by means of experiments allow for urgently required validation of the simulation concepts.

# Core-funded project "Arcs"

Significant improvement of process efficiency and reliability of electric arc-based technologies, such as electric arc welding or gas and vacuum switching technology, requires detailed knowledge on the properties and dynamics of relevant plasmas. In this aspect, special attention is given to the plasma-boundary areas, such as electrodes and walls. The interaction between plasma and the ambient medium is of great importance in all arc-based technologies. Therefore, analysis of the physical processes in the arc plasmas and their surrounding by means of optical diagnostics and numeric modelling, as well as further development of these methods are the focus of the core-funded project "Arcs".

During the period covered by this report, methods of emission spectroscopy were advanced and specific methods of absorption spectroscopy were established for characterization of arc plasmas and cold regions. For analysis of highly dynamic processes in arc discharges a video spectroscopy technique was developed by coupling of imaging spectrographs with high-speed cameras. This ensures recording of spatially one-dimensional spectra with a frame rate of up to 20,000 fps. From these images, physical parameters, such as radial profiles of the plasma temperature can be determined with corresponding temporal and spatial resolution. Also, a method for determination of two-dimensional plasma temperature profiles with high temporal resolution was developed through evaluation of spectrally filtered high-speed images. Substantial competence expansion was achieved through development of absorption spectroscopy methods for cold plasma regions. For these methods, either a highly intensive white light source is used as background source or tuneable laser diode system based on acoustic-optical modulators. These methods have already been used both in model setups and in the experiments with realistic operation conditions, such as switching arcs in vacuum or the tungsten inert gas welding. In addition, development of efficient two-colour pyrometry that has relatively low sensitivity to the arc plasma radiation was performed for determination of the surface temperatures of e.g. the weld pool or the metal droplets in the gas metal arc welding.



The figure on the left shows a high-speed camera image of a vacuum arc between cylindrical electrodes with the formation of a distinct anode spot, a cathode jet and a small cathode spots. The figure on the right presents the model vacuum switch with a chamber (top) and a pneumatic drive (bottom).

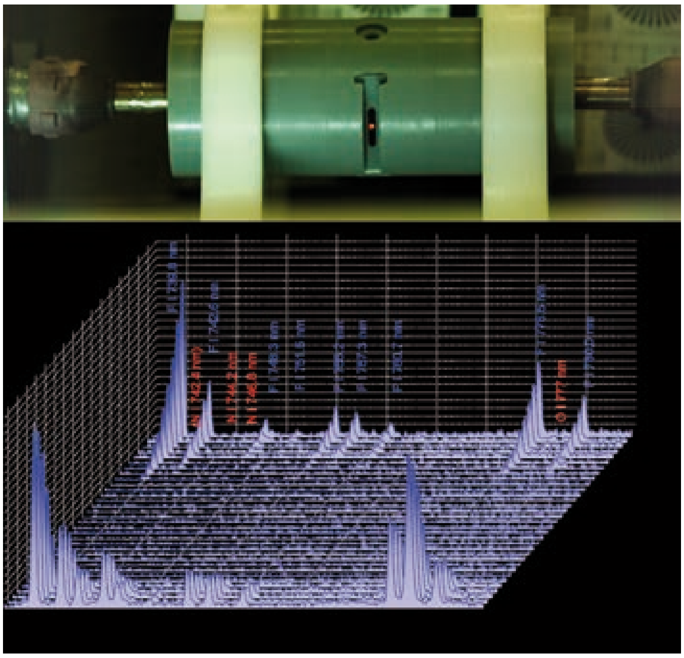
Considerable work has been performed in the core-funded project, especially for the analysis of arc attachment at the anode in vacuum. For this purpose, a setup for imitation of the processes in a medium- voltage switch was built. It consists of a vacuum chamber with optical ports, integrated adapters for real contact systems, as well as a drive unit for contact separation. The anode phenomena that are critically for the switching capacity of vacuum switches were analysed by means of high-speed camera technique and spectroscopy. The formation of anode spots results in increased electrode erosion and formation of metal vapour, which may significantly decrease the dielectric strength of the contact gap after current zero and, thus, cause the fail of current interruption. Special spot modes, such as anode spot of type 2 occurring at high-current densities and a mode referred as anode plume have been systematically analysed for the first time.

# Third-party funded project "Analysis and modelling of switching arcs using spectroscopic methods"

Modern gas-type circuit breakers used as major safety element in power grids use the principle of self-quenching. In these devices, the ablation of nozzle material due to the arc radiation is used for pressure build up in a heating volume and for the arc quenching due to corresponding flow of cold gas. One of the priorities in switching applications is the replacement of the environmentally harmful quenching gas sulphur hexafluoride by alternatives, like e.g. by carbon dioxide. For the switching capacity of these switches, the period for current zero and the phase directly after current zero are of special importance. Effects, such as reverse flow in the heating channel, change-over from a ablation dominated arc to an axially blown arc, extinguishing of the arc and evaporation of the nozzle material have so far only been insufficiently understood.

The objective of the project is the investigation of those effects and their influence on the transient behaviour and the dielectric strength of the switching path including complete modelling on the basis of circuit breaker simulations. Operated at a practice-oriented model switch with peak currents of several kilo-ampere, three experimental model groups are used: a) resistance measurement along the arc with spatial resolution over the entire arcing time; b) optical emission spectroscopy of the arc radiation; and c) absorption spectroscopic analysis of nozzle evaporation. Complementing this analysis, arc simulations along the switching path, including quantification of nozzle evaporation after current zero, were performed. Based on the input data from the simulations (temperature, density, gas composition), modelling of the dielectric strength and the spatially-resolved breakdown path is then carried out.

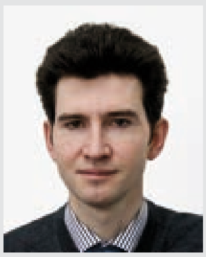
So far, interesting results have been obtained from optical emission and absorption spectroscopy, among others. For example, emission spectroscopy evaluation could be expanded to a time range of up to 100 micro-seconds before the current zero and, thus, allows for the analysis of the change-over from ablation dominated to axially blown arc regime.



The top image shows the setup for optical diagnostics of the switching arc through a window in a polytetrafluoroethylene nozzle. Spectra around the current zero at a peak current of 8 kA obtained by means of video spectroscopy are displayed in the bottom image.

Joint project with the Institute for High Voltage Technology of RWTH Aachen – sponsored by DFG, from 01/2016 to 04/2018 (UH 106/13-1)

## CONTACT



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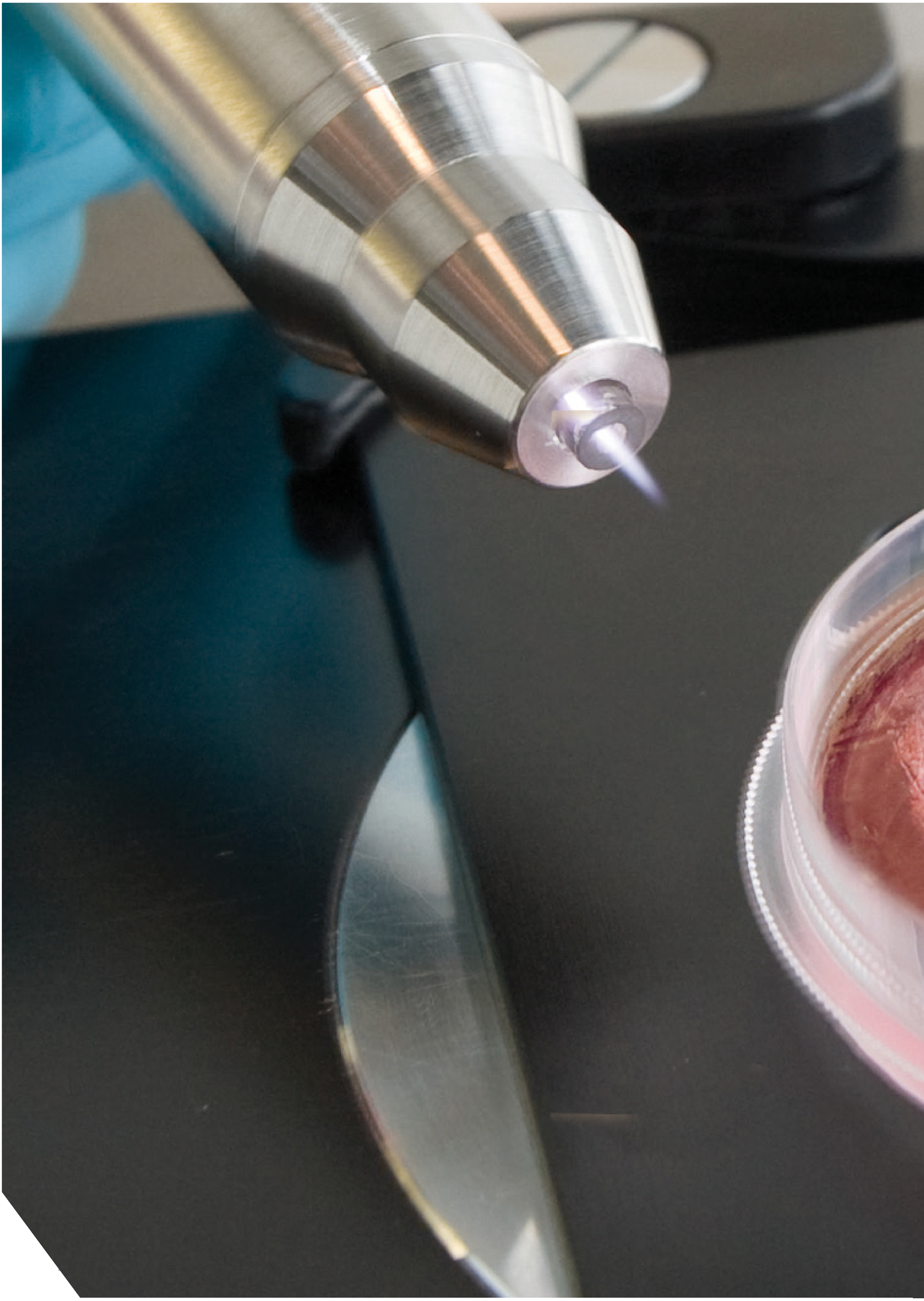


# RESEARCH DIVISION

# ENVIRONMENT & HEALTH

## Overview

The Research Division Plasmas for Environment and Health operates in a multidisciplinary way and utilises the synergies of its three research focuses: bioactive surfaces, plasma medicine and decontamination. In this context, the plasma sources at atmospheric pressure are an essential link. The comprehensive experimental examinations include dielectrically encumbered discharge, jet, microwave and micro-plasmas. In this division, the close collaboration of physicists, biologists, chemists, pharmacists, medical experts, and engineers with highly specialised technicians and laboratory specialists is unparalleled in the world.

In plasma medicine, the focus is on fundamental research for interactions of physical plasmas in living cells and tissues. In addition, exploration and introduction of plasma-based processes in medicine is promoted. In the field of bioactive surfaces, custom-made surfaces for applications in the life-science area are scientifically investigated. Another priority topic is plasma-based decontamination: the focus here is on exhaust air purification and disinfection of food and water, among others.

## Research Programme Bioactive Surfaces

- Ceramic and biomimetic coat systems for use in the medical field
- DEFOE – disc etching for one-cell electrophysiology

## Research Programme Plasma Medicine

- Plasma & cells
- Centre for innovation competence (ZIK) "plasmatis – plasma plus cell"

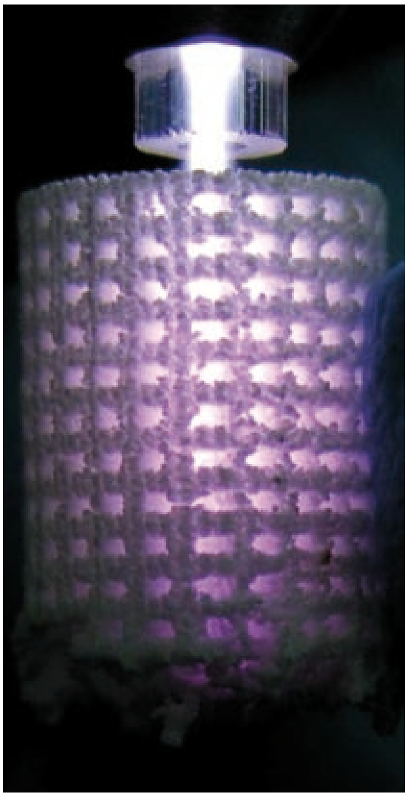
## Research Programme Decontamination

- Plasma-chemical processes in liquids
- Plasma and food

# Overview

For applications in the life-science area (e.g. hygiene, medicine, and biotechnology), surface modification of the products is required to generate specific properties. Depending on the modification process used, the wetting properties of surfaces can be controlled such that they are more hydrophilic or hydrophobic, or that specific chemical functions are generated on the surface to improve biological compatibility. Especially plasma-based processes allow for chemical and morphological modification of surfaces in a wide range and variation so that the application spectrum is significantly increased. For improvement of the surface compatibility of biomaterials and for initiation of specific reactions of the biological system in contact with the surface, these are functionalised by the use of low-temperature plasmas. Plasma coating, for example, generates new specific properties for biomedical and biotechnological applications, nearly completely independent of the substrate geometry and the material.

Since process costs and easy integration of the plasma process into existing productions lines, particularly in industrial applications, is of paramount importance, the INP offers both low pressure processes for highest cleanliness/purity and atmospheric pressure processes for short processing times.



## Fields of application

### Anti-microbial surfaces

Anti-microbial surfaces are mainly used in infection prevention. Especially implants, tweezers, scalpels or other medical tools and products that come into direct contact with the patient require great attention to this end. To prevent colonisation of surfaces with pathogenic bacteria, various plasma-based processes are used for generation of photo-catalytically active surface modifications on the basis of titanium oxide, which have anti-bacterial or self-purifying properties if irradiated with UV light, or generation of anti-microbial coatings whose bacteriocidal effect is based on metallic compounds, such as copper or silver. To generate a possibly long-term anti-microbial effect, metal particles can be embedded in a polymeric or glass-like matrix. In this way, it is possible to control the release behaviour of the anti-microbial additives, for example.

### Cell-adherent surfaces

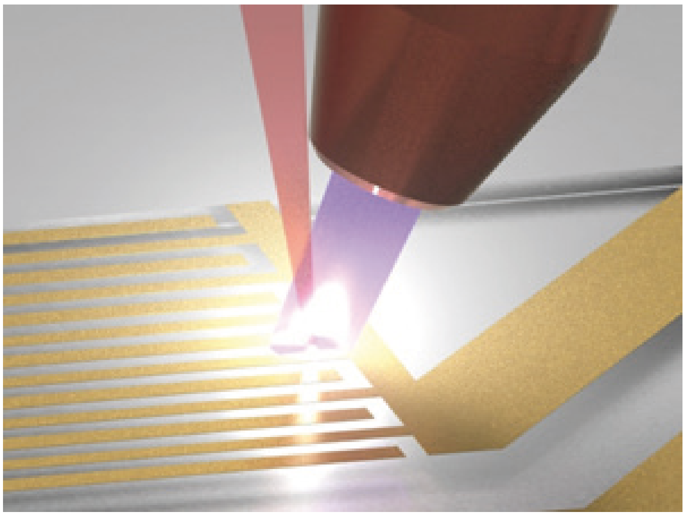
Plasma processes are particularly well suited for equipping surfaces with reactive, chemical groups, such as amino or carboxyl groups, which significantly improves the cell response, especially cell density, cell distribution, as well as adhesion, proliferation and differentiation. Moreover, the connection of bio-molecules by means of different immobilisation strategies, such as covalent coupling of linkers and spacers is possible.

### Anti-adhesive surfaces

Especially for transient implants, such as fixations or temporary screw connections anti-adhesive surface properties are of great benefit. Moreover, such surfaces are easy to clean, since there is hardly any adhesion of dirt and oil/grease or organic material. Application of such surfaces is easily and cost-efficiently implemented by means of plasma technology.

# Application-oriented outlook – hybrid processes

## Laser plasma processes



Economic success in medical engineering, diagnostics and sensor technology requires continuous research and development of innovative products and manufacturing processes. These generally are subject to the most stringent requirements in terms of precision, quality, and reproducibility and at the same time must cater for a large range of various materials. Within the scope of advancing miniaturisation and increasing function integration, product and component surfaces must also assume special functions to achieve favourable medical or biological properties.

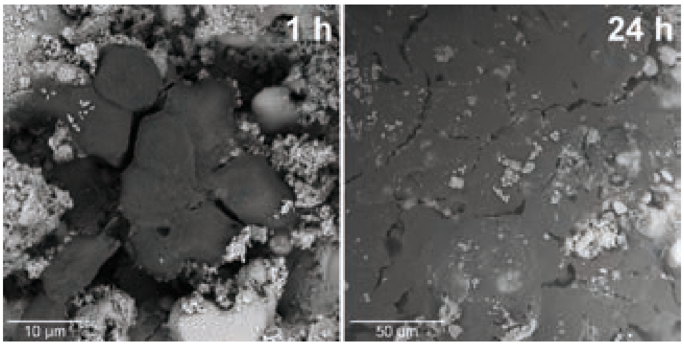
The combination of innovative technologies allows for ultra-precise processing, which is critical particularly for industrial manufacturing. Laser plasma hybrid processes can be used for both coatings and highly precise material removal and can be applied as either local or large-surface process variants. In this way, materials can be functionalised by means of atmospheric pressure plasmas and, in combination with laser pulses, targetedly coated or structured with lateral dimensions down to the micrometre range.

# Core-funded project on ceramic and biomimetic coat systems for use in the medical field

The requirements for implant materials with regard to properties and structure are greatly varied. Depending on the field of application and functionality, high mechanical load-bearing capacities (ultimate tensile strength) and biological compatibility (bio-compatibility) are indispensable. The most frequently used materials for implants include metals and their alloys, as well as ceramic and polymeric materials. These mostly are technical materials that in some cases are not suitable for biological applications.

However, due to chemical surface properties, specific reactions, e.g. intergrowth and coalescence with bones (osseointegration) may be promoted. Atmospheric pressure plasma spraying (APS) is an established process for surface modification, which provides a large number of advantages. With this process, large workpieces can be coated with thick layers of up to several millimetres. In APS, particles of sizes between 5 and 200 µm are sprayed into 16,000 °C hot plasma, which are then partly or completely melted and hit the substrate to be coated at speeds of up to 450 m/s. With this technique, the substrates to be coated are not melted so that neither their crystalline structure or their chemical and mechanical properties are modified. In the medical field, plasma spraying is highly attractive for production of implants. The main priority is to achieve biological, chemical and physical modification of the interface between the implant and the tissue to improve functional compatibility.

The implants are equipped with a titanium or titanium oxide coat with defined roughness and thus significantly improves intergrowth of the implant with the bone, among others. With the same process, coats have been generated that simulate the natural physiology of the bone and thus promote direct contact between the implant and the bone. For that purpose, bone-like substances, such as hydroxyl apatite or tri-calcium phosphate are separated. Moreover, there is an option to additionally equip the coats with anti-microbial agents (e.g. silver, copper, or zinc). These are released during the period directly after implantation and prevent bacterial colonisation of the bone. A common feature of all APS coatings is their high degree of roughness and porosity. In medical applications, roughness plays a particularly great role since it makes it easier for osteoblasts to adhere.



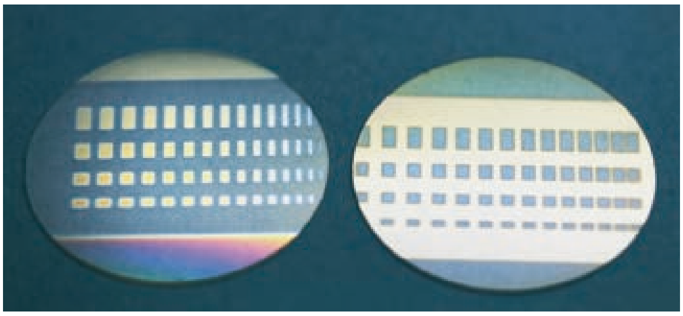

Growth of bone-like cells after 1 h (magnification 6000x) and after 24 h (magnification 1500x) on a plasma-sprayed hydroxyl apatite coating.

# Externally funded project DEFOE – Disc Etching for One-cell Electrophysiology

Far more than 1000 research laboratories all over the world are working on examining cells from brain and other types of tissue by means of electrophysiological methods. The exchange of information between a large number of individual cells is based on chemical and electrical signal transmission. However, to obtain detailed insights of the cellular processes, electrical activity must be directly deduced from individual cells or small-scale cellular networks. In this way it is possible that only one cell responds to an individual stimulus without any interfering signals by thousands of other cells. To reveal the functions of the individual cellular components, it is required for the cells to be cultivated in nutrient solution, isolated from one another. However, to make sure that cells adhere to and grow on inorganic substrate surfaces chemical surface modification is required. Based on this surface modification, geometric control of cell adhesion and cell growth is possible. This process is referred to as cell patterning. Functionalisation of these materials is performed e.g. with simple chemical groups through various plasma treatments.

The objective of the DEFOE research project was the development and optimisation of cell culture carriers with the help of plasma coating to ensure geometric control of the cell growth on two-dimensional substrate. For that purpose, functional molecules in micro-structures were deposited on the surface (e.g. polystyrene) by means of the process of plasma-enhanced chemical vapour deposition (PE-CVD). Depending on the composition of the plasma used, substrate regions were produced which promote cell adhesion and growth while the remaining substrate surface had cell-repellent properties. As a consequence, it was possible to greatly focus regional cell growth in micrometre ranges.

The plasma coatings to be applied are very thin (20 – 100 nm) and do not have an effect on spectroscopic examination of the cells; compared with cell carriers produced by conventional technologies, the expected auto-fluorescence is very low.
This production technology allows for reproduction of structures in the most varied geometries and sizes on various types of substrate surfaces.



Structured substrate surface after plasma treatment

## CONTACT

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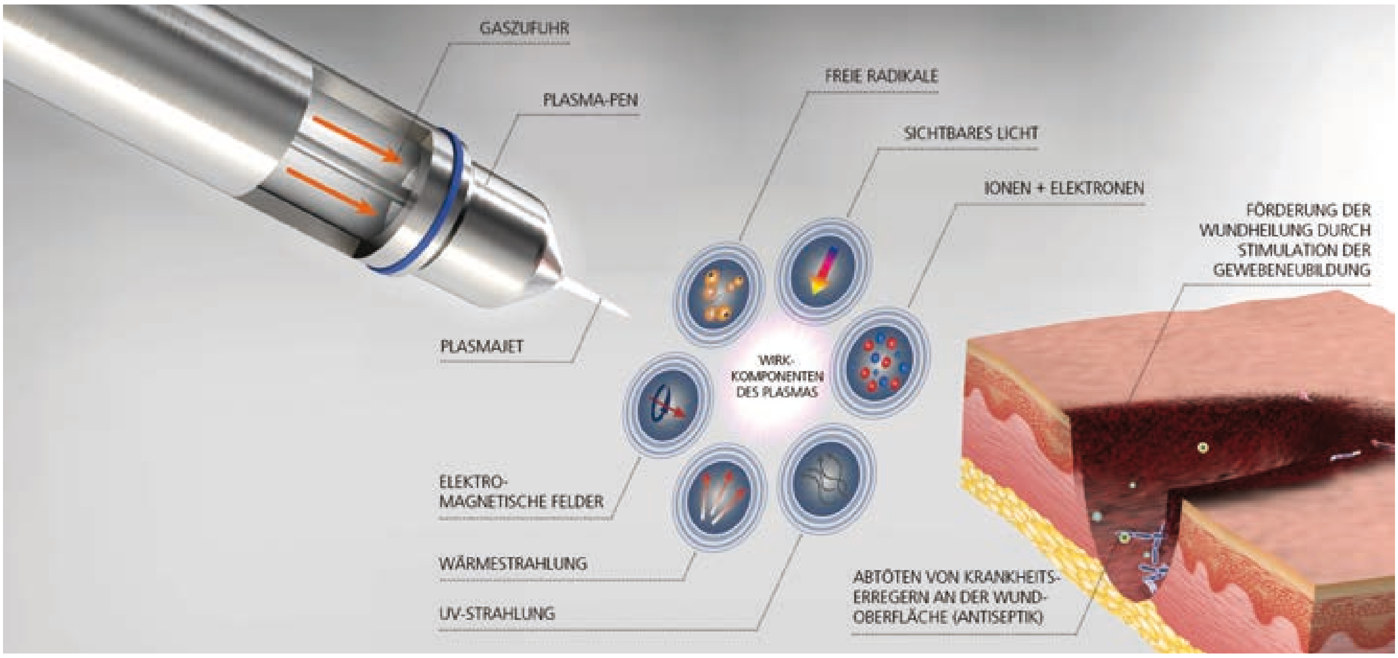
## Overview




Two-stage concept of plasma-enhanced wound healing. Atmospheric pressure plasma jet used as the source of biologically active plasma components

Plasma medicine is an innovative research area at the interface between physics and life sciences, which is focused on medical use of physical plasmas, particularly cold atmospheric pressure plasmas. By means of cold atmospheric pressure plasma, biological processes in living cells and tissues can be specifically influenced. In addition to effective inactivation of microorganisms, including multi-resistant pathogens, regeneration of traumatic tissue is stimulated, which promotes wound healing processes. Under certain conditions, destruction of cancer cells is also possible.

The use of cold plasma for the healing of wounds and pathogenic skin diseases meanwhile is clinical reality. The first cold plasma devices have been granted marketing approval. The atmospheric pressure plasma jet kINPen that was designed and thoroughly examined at INP has been further developed by neoplas tools GmbH Greifswald to become a marketable product under the name of kINPen® MED 2013. It has been CE-certified as class II medical device and is meanwhile increasingly used, particularly for treatment of chronic wounds.

Using a wide range of microbiological as well as cell- and molecular-biological methods, the research programme Plasma Medicine performs laboratory research on the effects of cold atmospheric pressure plasmas on microorganisms, cells and tissue.

The results of several years of fundamental research have revealed that biological plasma effects are largely mediated by reactive oxygen and nitrogen species and thus influence cellular redox processes. Based on this work, the research programme Plasma Medicine was able to build up considerable expertise beyond plasma research, particularly in the field of redox biology useful for interdisciplinary cooperation.

The goal of the application-oriented research work within this research programme is to gain detailed understanding of the active mechanisms for optimisation of medical plasma applications and for ensuring application safety to the highest degree. In cross-disciplinary cooperation, specific biological effects are to be specifically controlled and regulated by means of modification of plasma parameters. The paramount objective of this work is continuous improvement of characterisation and control of the physical properties of cold atmospheric pressure plasmas in interaction with living systems to design and optimise plasma devices for medical applications and thus explore new fields of application. On the basis of long-term plasma-physical and technical engineering expertise in research and testing of cold atmospheric pressure plasma sources, application-specific new and further developments of medical plasma sources and their introduction into medical practice are performed in cooperation with partners from the industry and the medical field.

# Application-oriented outlook – perspectives of plasma medicine

Since cold atmospheric pressure plasmas have generally found their way into medicine, the challenges plasma-physical and plasma-technical research and development are faced with now is to design new and optimised plasma sources for specific application requirements and to prepare them for practical use. In this context, three main working goals will need to be pursued in the coming years:

- Conception and testing of plasma sources for specific medical fields of application for treatment of larger areas, for endoscopic application and for application in body cavities, as well as plasma sources for dentistry
- Exploration of options for application-related control, monitoring and modification of plasma parameters to achieve selective and variable biological effects and to have device-independent parameters available for control and regulation of medical plasma effects.
- Identification and use of application-specific advantages and disadvantages of jet-based plasma sources in comparison with plasma sources on the basis of dielectric barrier discharge (DBE) with and without the use of prefabricated working gasses.

In application-oriented plasma-medical fundamental research, the focus in the coming years will be on the following areas:

## WOUND HEALING

Since plasma-enhanced wound healing has been established, particularly for treatment of chronic and/or infected wounds, further pre-clinical and clinical research projects are required for optimisation of the therapy (frequency, duration and localisation of the application of plasma), accompanied by experimental laboratory work. Moreover, the option of using plasma for example in acute (problematic) wounds, infected catheter exit points and pathogenic skin and mucosa diseases must be tested and expanded further.

## CANCER TREATMENT

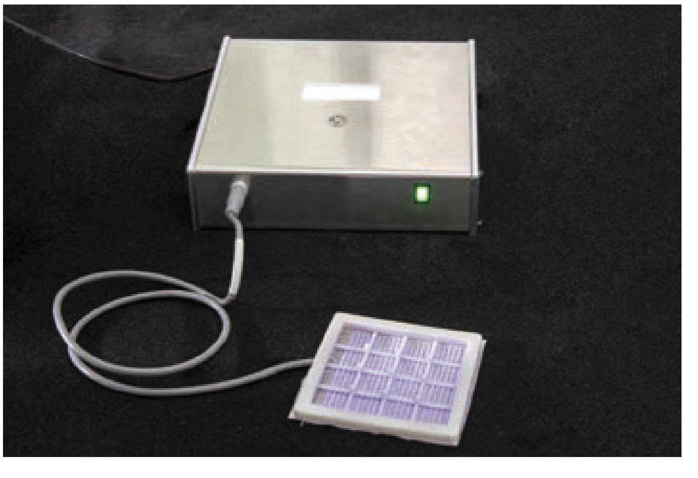
Depending on the intensity of the plasma treatment, cells may be inactivated by induction of programmed cellular death (apoptosis). This is also possible for cancer cells, which results in the option of using cold plasma within the scope of surgical tumour resection for deactivation of remaining cancer cells, particularly in circumstances where large-scale surgical operation is not possible due to the proximity of sensitive anatomic structures (major blood vessels, nerve tracts, etc.).

## DENTISTRY

The potential options for application of plasma in dentistry are highly versatile and include applications directly at the teeth, at implants and prostheses, as well as the oral mucosa. Utilisation of the anti-bacterial and anti-inflammatory plasma effects for treatment of periimplantitis and in endodontics is at the centre of the scientific interest.

## PLASMA-TREATED LIQUIDS

Biological plasma effects are not only mediated by means of modifications of the liquid cell environment; liquids, such as water, physiological sodium chloride solution or a cell culture medium may also become temporarily biologically active after plasma treatment. Currently, the potential options for use as disinfectants, antiseptics and application in cancer therapy are explored.



Large-surface, dielectric barrier discharge (DBE) on the basis of a textile electrode configuration

# Core-founded project “Plasma & Cell”

Prior to the beginning of 2017, the research department for plasma medicine was almost exclusively dependent on external funding for personnel within the scope of two state and national government-funded projects. From the beginning of 2017 it was possible to transfer major scientific tasks from these sponsored projects to the core-funded project “Plasma & Cell” and continued within that framework.

## WOUND HEALING – ANIMAL EXPERIMENTS STUDY

In cooperation with the Rostock University Medical Centre a study was performed on wound healing in mice. Under controlled and reproducible experiment conditions we were able to demonstrate that healing of acute, non-infected wounds is stimulated by plasma treatment, which can be proved by molecular biological markers. Moreover, subsequent monitoring of the plasma-treated animals throughout one year revealed no indications of any carcinogenic plasma effects. So, for the first time it was possible to provide evidence for the safety of plasma treatment due to a controlled in vivo study.

## WOUND HEALING – CLINICAL RESEARCH

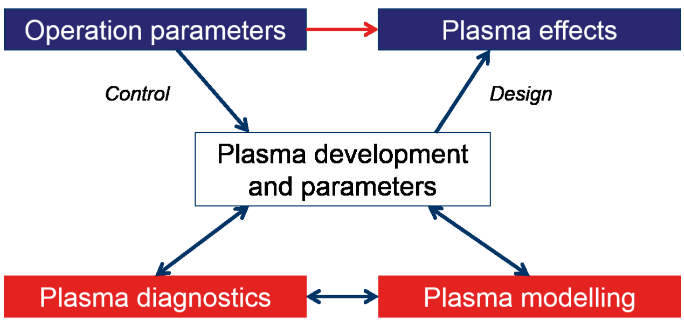
In cooperation with the Karlsburg Clinic, Centre for Cardiology and Diabetes, Mecklenburg West-Pomerania, exudate from chronic wounds is analysed before and after plasma treatment. The paramount aim is a detailed characterisation of the anti-microbial effect of plasma in vivo. Moreover, in combination with innovative diagnostics using a hyperspectral camera (Diaspective Vision GmbH, Pepelow), the wound healing process can be monitored in general and the sustainable effect of the plasma in particular. This work is performed by the permanent research group “Plasma wound healing” that originated from the first funding phase of ZIK plasmatis.

## PLASMA SOURCE CONCEPTS

The second permanent research group “Plasma Source Concepts” that also originated from the first funding phase of ZIK plasmatis had their operational focus on conception and testing of plasma sources for dentistry applications (kINPenDent), endoscopic applications (kINPenFlex) and large-area jet-based plasma sources or textile-based DBE electrode structures. An integral part of this work was taking into account the prerequisites for future certification of the plasma sources as medical products and testing of such products on the basis of the developing DIN SPEC 91315.

## EXPERIMENTAL FOUNDATIONS FOR NEW MEDICAL APPLICATIONS

Using melanocytes it was demonstrated that formation of melanin is affected under the impact of plasma, which forms the basis for further research with regard to plasma applications for treatment of pigment disorders of the skin. The combination of plasma and pulsed electric fields for treatment of tumour cells particularly resulted in an increased migration- and proliferation-inhibiting effect, which in turn might result in further application options for plasma in cancer therapy. Plasma-treated physiological sodium chloride solution was examined for its applicability as disinfectant and antiseptic in various experimental approaches. An important outcome was the proof that proteins act as inhibitors of the anti-microbial effect.




Basic elements of plasma device characterization as precondition for effective medical device development

# Externally funded project – Centre for Innovation Competence (ZIK) "plasmatis – plasma plus cell"

From 2009 to 2015 it was possible to lay the overall foundation for a topical leadership of the INP in the new research field of plasma medicine by operation of the Centre for Innovation Competence (ZIK) "plasmatis – plasma plus cell", an unique combination of expertise of biochemists, pharmacists, biologists and physicists. On the basis of the positive results obtained during the first ZIK phase which was funded by the German Federal Ministry of Education and Research, in 2015 a second funding phase was started for establishment of two new junior research groups. The paramount goal of ZIK plasmatis is to consolidate and expand the international topical leadership of the INP in the field of basic research in plasma medicine.

The JUNIOR RESEARCH GROUP "PLASMA REDOX EFFECTS" assumed their work in January 2016. The focus of their work is on exploration of the cell and molecular biology options of a redox-based anti-tumour strategy and immunotherapy by means of cold plasma to open up new options in cancer therapy. Especially this junior research group has available considerable expertise in the field of redox biology, which forms the basis for future research activities and cooperation projects beyond plasma medical fundamental research. The in-depth understanding of redox biological processes will yield insights on pathology and therapeutic options for a great number of diseases.

The JUNIOR RESEARCH GROUP "PLASMA LIQUID EFFECTS" assumed their work in February 2017 and concentrates on systematic analysis of chemical molecules that are introduced into biological liquids and systems by means of cold plasmas, and their contribution towards the efficiency of medical applications and their modulation through technical modification of the plasma source. They will provide statements on the effective principles of cold plasmas in biological systems and form the foundation for specific adjustment of a plasma source to the requirements of the respective individual fields of treatment.

The two junior research groups from the first funding phase were included in the INP as permanent scientists groups "Plasma Source Concepts" and "Plasma Wound Healing" and are now an integral part of the core-funded project "Plasma & cell", thus functioning as an interface between ZIK plasmatis and the other research activities of the research programme Plasma Medicine.


Cross-linking of the new junior research groups (red) with the permanent research groups (blue) of ZIK plasmatis.

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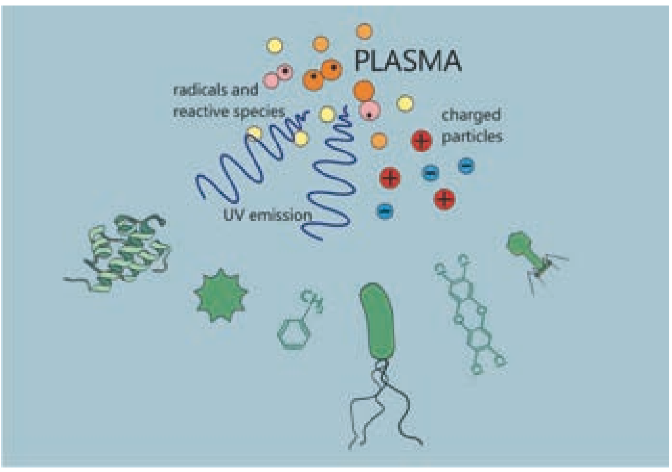
# Overview

This research focus concentrates on analysis, development and optimisation of plasma-based methods and processes for decontamination, hygienic processing for environment protection, for occupational and personal safety, in food hygiene, and for germ reduction in medical facilities and domestic care. In this context, plasma technology is used for reduction of biological and chemical contamination of gasses (particularly air), liquids (particularly water), and surfaces, where the latter also and above all includes fruit and vegetables.

For decontamination purposes, the chemically reactive species formed by plasmas, but also other active mechanisms, such as ultra-violet radiation and electric fields, are directly and indirectly used. Depending on the type of application, these may be more or less distinct in the different plasma sources. However, one feature that all approaches have in common is the use of relative cold plasmas, which is particularly advisable for temperature-sensitive materials and products that are not suited for thermal decontamination processes.

A major benefit of plasmas for decontamination over other processes is that reactive chemistry and decomposition mechanisms can be strategically controlled simply by provision of the correct type and mode of electrical energy. Especially short-lived reactive species, such as hydroxyl radicals, can be directly generated from and within the medium (e.g. air or water) to be purified. Accordingly, no long-term damaging reaction products are expected.




Electrical discharges are efficient means for the generation of plasmas. Concurrently different reaction mechanisms are provided that can be exploited for the degradation of recalcitrant chemical compounds, biomolecules and microorganisms.

## Fields of application

### Clean air

The "clean air" research topic addresses the development of new plasma-based processes for decomposition of pollutants in gas flows, including air. In combination with other processes, e.g. filter systems, their overall aim is decomposition of substances that can hardly or not at all be removed by other methods. Plasma in the form of the Advanced Oxidation Technology represents a promising approach.

### Clean water

The "clean water" research topic addresses microbial and chemical decontamination, particularly for processing of potable and waste water. Liquids may be temporarily equipped with antimicrobial characteristics. A complementary approach is the generation of plasma, especially in the water, itself, which directly attacks the microorganisms and micro-contaminations, such as pharmaceutical residues.

### Clean food

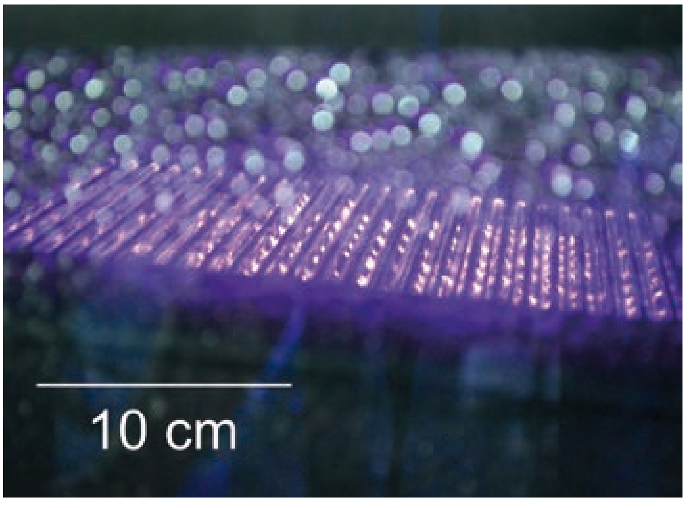
The "clean food" research topic addresses development of direct and indirect plasma treatment for the food industry. The purpose is to keep transport paths and packaging microbially clean but also to preserve fruit and vegetable after harvesting in a gentle manner and thus increasing shelf life.

### Clean healthcare

The "clean healthcare" research topic addresses plasma-based biological decontamination and possible sterilisation of sensitive materials and medical products. For that purpose, plasma sources are specially developed to meet the medical requirements, e.g. for endoscopy.

# Application-oriented outlook – plasma treatment of liquids, disinfectants and decomposition of pollutants

Treatment of liquids by means of plasmas generated by gas discharge is possible on the basis of various approaches. Generally, three different procedures can be classified. On the one hand, plasmas can be generated in gasses, preferably ambient air, to form chemically reactive substances, such as ozone, which are then introduced into the liquid. For plasma generation, the liquid may also be directly integrated into the plasma process, e.g. in the form of an electrode, which allows for the reactive species generated in the gaseous phase to directly seep into the liquid. In addition, radiation and electric fields from the plasma may interact with the liquid surface. For the last method, plasmas are directly generated in the liquid itself by suitable electrode geometry and electric stimulation. Naturally, the different methods provide different options. Depending on the generation process, the chemical processes active within the liquid are the decisive differentiation features, which are either directly used for decontamination or indirectly for generation of a means of decontamination.




Large area dielectric barrier discharge for the treatment of water that is sprayed into the configuration. A plasma is generated between glass-coated high voltage and grounded electrodes by applying short high voltage pulses of 400 ns and 30 kV with a repetition rate of 1 kHz.

### Plasma-generated disinfectant

During the past two years and on the basis of analyses on the understanding of plasmas generated at water surfaces, systems were developed that allow for treatment of certain volumes and permit at least feasibility studies for various applications. By means of the WINPlas system developed by INP, it is now possible for users to treat water, particularly tap water, with plasma that imparts antimicrobial properties to the liquid. The disinfectant made available in this way is currently tested by various bodies as alternative cleaning agent for medical products, as a replacement for chemical sprays and for combatting germ growth in pool water.

### Plasma-based potable water processing

While antimicrobial processing of potable water does not represent a big problem in Germany and Europe, increased pollution by anthropogenic micro-contamination products, such as pesticides and pharmaceuticals are a big challenge since it was not possible to eliminate them by conventional processes. However, plasmas generated either in or at the water may be a potential solution. For this purpose, the INP developed a system for continuous flow water treatment by means of pulsed dielectrically impaired discharge. The system is currently under test with regard to its cleaning efficiency and is then going to be tested under real conditions at a reservoir used for potable water treatment.

### Plasma treatment of polluted waste water

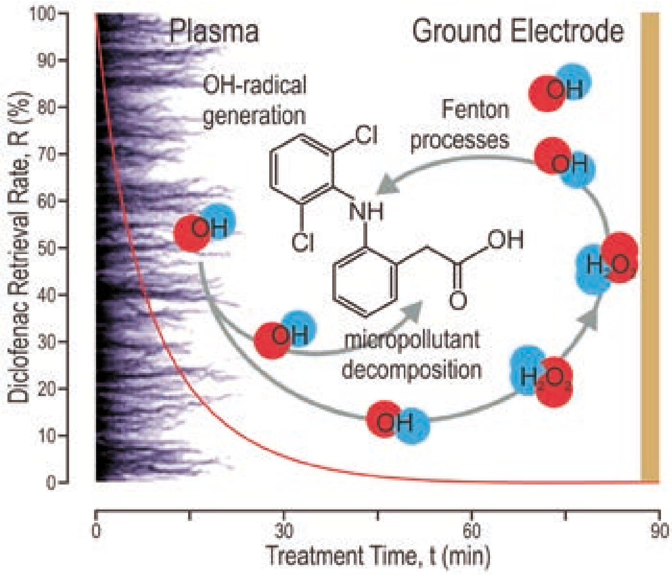
In waste water treatment, pulsed corona discharge generated within the liquid is the most efficient method for making available hydroxyl radicals in great concentrations in the areas where the contamination to be removed is located. Taking a scientific preliminary project sponsored by the BMBF as a basis, systems for processing of waste water from laundry facilities and sewage treatment plants are currently set up at INP to test the efficiency of the method under real conditions. The special focus is on the combination with other processes.

# Core-funded project
# – plasma chemical processes in liquids

The efforts of the research programme are characterised by the development of various plasma processes and technologies for decontamination in the most varied fields of application. The objective of all applications is a general understanding of the effects of the physical and chemical processes established by means of plasma on microorganisms and specific substances and molecules, including biomolecules. The chemical processes and process products generated under the effect of plasma have become increasingly important in recent years. These are not only dependent on the type of plasma and its operating parameters but above all from the parameters present in the water, such as conductivity, dissolved oxygen and nitrogen concentrations and the pH value. All these parameters change under the interaction with a plasma. In addition, biomolecules dissolved in water may also strongly affect the efficiency of the plasma treatment. For example, it has been revealed that the antimicrobial effect of the liquid chemistry induced by plasma is reduced in the presence of specific proteins and/or amino acids, particularly for nutrient solutions.

The long-term effect on microorganisms is mainly due to reactive oxygen and nitrogen species, for which proof was given that they also have a sustainable effect on the biochemistry of cells and bacteria, in addition to the oxidative mechanisms. For dielectrically impaired discharge, which is operated in ambient air, it could be demonstrated that e.g. superoxide, hydrogen peroxide, nitrite and nitrate in buffered nutrient solutions are formed in concentrations that vary depending on the introduced electronic energy.

While the use of a buffered nutrient solution rules out modification of the reaction kinetics depending on the pH value, they are of particular importance for treatment of water. The plasma process developed for food treatment is characterised by high NO concentrations, which form peroxide nitrite in aqueous solutions at low pH.




Primary (in plasma) and secondary (in water or at the ground electrode) chemical reactions through corona discharge generated in water and their interaction with the pollutants dissolved in the water.

Through corona discharge directly generated in water by pulsed high voltage, hydroxyl radicals are mainly formed in addition to short-lived reactive molecules, which are characterised by their high reactive potential. However, this potential also results in their easy transformation to hydrogen peroxide in case that they do not encounter other reaction partners. Consequently, these analyses revealed the necessity of taking into account and utilising the subsequent electrode chemistry for the overall decomposition of pharmaceutical residues to re-transform hydrogen peroxide into hydroxyl radicals.

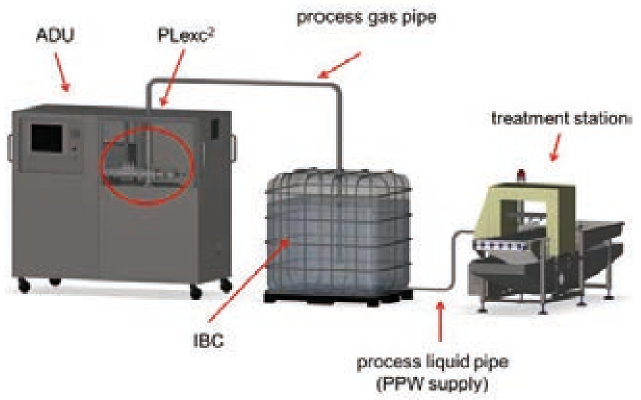
# Externally funded project – plasma and food

Within the food production chains of vegetable foods, germ growth may cause problems in terms of food safety and lead to crop and storage losses. Producers and processors of fresh products are highly interested in the reduction of such hazards and subsequent losses due to the direct economic consequences.

Deactivation of microorganisms on natural surfaces and simultaneous retention of valuable constituents of the vegetable matrix is a technological challenge. Due to the great cost pressure, only relatively cost-efficient processes can be used. The core idea of our research work is to generate efficiently acting antimicrobial species, particularly radicals and metastable systems, that are microbiologically active on the one hand, and are decomposed within the typical process periods, so that potential effects on the product are minimised and risks for the consumers are ruled out. The goal of decontamination of food by means of plasma is to ensure yield improvement and simultaneously increase safety for consumers. Other fields of application are e.g. packaging, transport containers, system components and medical products.

Ideally, the reactive nitrogen and oxygen species preferred for the decontamination process can be directly generated from the ambient air. For this purpose INP developed the microwave-based plasma source PLexc, which particularly generates nitrogen species in high concentration rates under atmospheric pressure. By accumulation of these species in ambient air, antimicrobial effects on various surfaces can be directly achieved. The effect of air treated by this method on freshly cut broccoli for a period of only 15 minutes was a germ reduction by more than 5 log levels. However, the colour and structure of the produce were also changed due to the treatment. Further analyses, e.g. for other types of food, but particularly with regard to food quality after treatment are required.

Another very promising approach is to dissolve the reactive species generated in ambient air in water, as is already done in conventional cleaning processes for fruit and vegetables. In this way it would be possible to replace the chemicals, e.g. chloride, frequently used in such cleaning processes. The germ-killing effect for lettuce that has already been established in laboratory tests has meanwhile led to development of an industrial demonstrator, in which 1000 l of water can be enriched with reactive species generated in plasma.




Industrial-suited autonomous system (ADU = auxiliary decontamination unit), in which 1000 l of tap water can be enriched with reactive species generated from ambient air by two-stage plasma treatment (PLex^2) for the subsequent washing processes.

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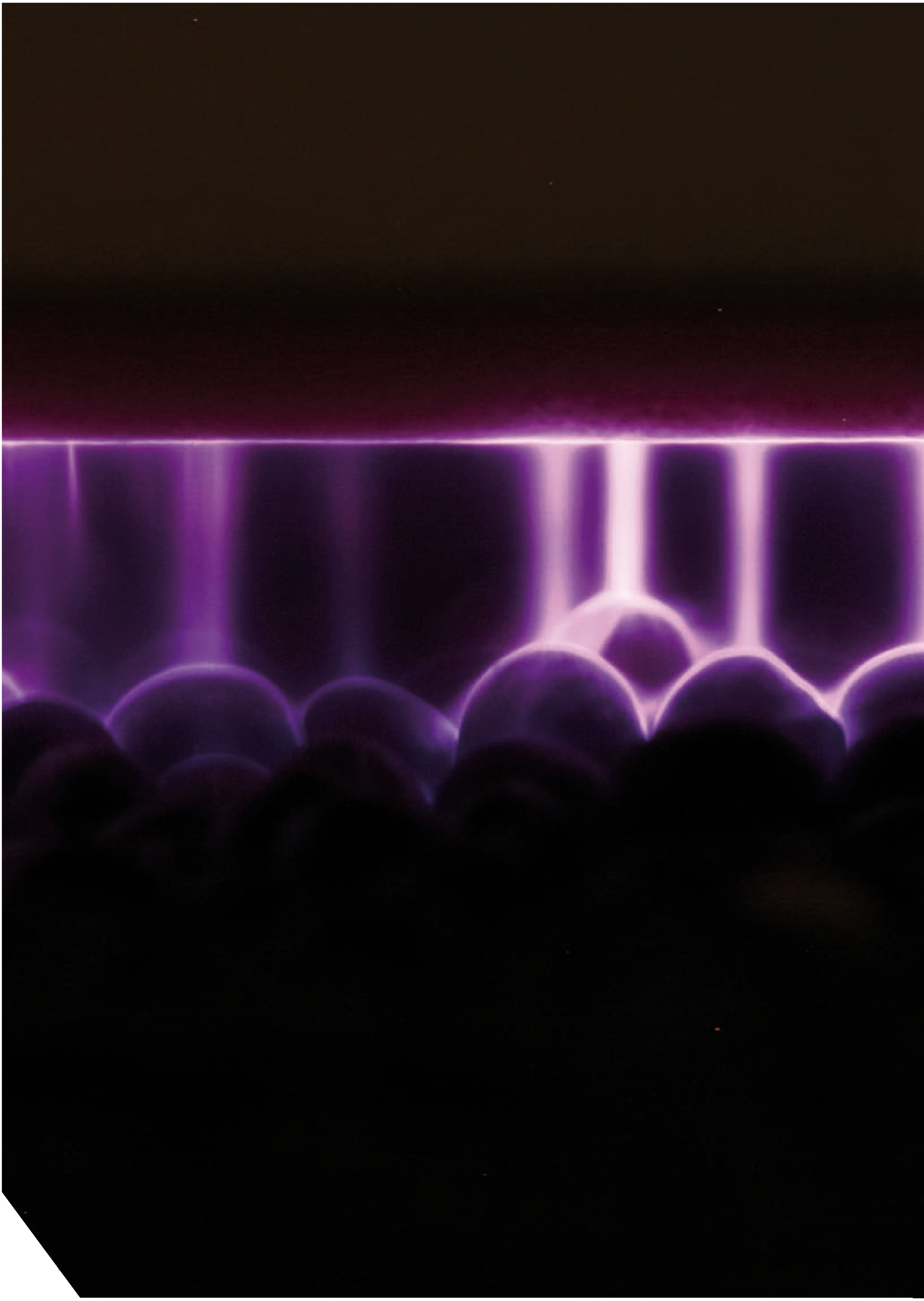


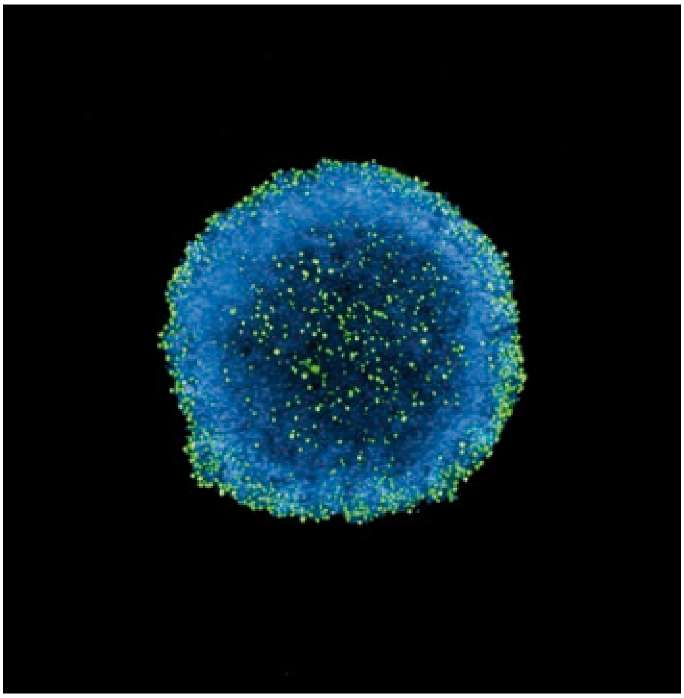
# RESEARCH GROUPS

## Overview

The successful scientific work of the Centre for Innovative Competence "plasmatis" is continued in the second sponsored phase with two new junior research groups for "Plasma Liquid Effects" and "Plasma Redox Effects". The research groups from the first sponsored phase have been integrated as permanent research groups and an additional junior research group in the field of "biosensoric surfaces" was established for which self-funding has been granted.

The junior research groups address cross-disciplinary research topics in a largely independent manner, without any operative activities or research commissions. This is a great opportunity and support for junior scientists to gain initial managerial experience and establish their own profile.

# ZIK plasmatis
# – plasma redox effects



Three-dimensional growth of a tumour spheroid from human melanoma cells after cold plasma treatment; the green sections represent the tumour cells killed by the plasma treatment.

Reactive molecules ("free radicals") function as mediators for biological plasma effects. They affect the "redox" processes of cells. The molecules produced by plasma are equal to those generated by physiological processes in body cells and may also function as signal molecules. The type of cell response triggered depends on equipment of the cell with enzymes, as well as the quality and quantity of the species generated by plasma. Through the course of many diseases, such as cancer, the enzyme equipment changes. This allows for therapeutic effects of plasma treatment.

The junior research group for "plasma redox effects" performs fundamental research at the interface of many different research disciplines. These include redox biology, plasma medicine, oncology, and immunobiology. The team works with tumour and immune cells in two- and three-dimensional cell culture models, primary cells, animal models and patient samples.

Advanced cancer stages present two major challenges for both patients and medical practitioners. On the one hand, cancer cells spread through the entire body (metastases) so that they can hardly be reached by therapies, causing 90% of the deaths resulting from cancer. On the other hand, these cancer cells actively downregulate detection by immune cells. The junior research group explores the extent to which cancer cells can be made visible to the immune system through plasma treatment. By this, immune cells that fight cancer cells are generated in the entire body. This principle has already been known from other forms of therapy that also produce reactive species. Whether or not plasma plays a role in establishment of anti-tumour immune responses is analysed by means of skin cancer models, among others.

We were able to demonstrate that plasma has a toxic effect on both metastasising and non-metastasising tumour cells. In addition to melanoma, this also holds true for a number of other types of cancer, such as colorectal, pancreas, and breast carcinoma, as well as various forms of leukaemia. In addition, we also found that plasma has a cyto-toxic effect on tumour cells with three-dimensional growth, i.e. spheroids. In this scenario, direct plasma treatment was more effective than treatment with plasma-treated liquids.

We have established a number of laboratory methods for making the interaction between tumour cells and immune cells visible. In phagocytes, plasma treatment induced a mixed phenotype with partly tumour-toxic properties. We have characterised the inflammatory profile of tumour cells and immune cells after plasma treatment, which reduces the overall growth of tumour cells.

A concise library of plasma-treated primary human skin tumours was created, which will be useful in clarifying the effective mechanisms of plasma.

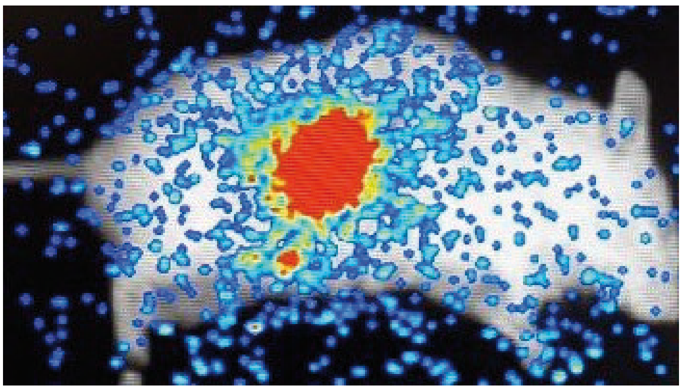
The research focus is going to be on three major topics. Firstly, plasma treatment of tumours will be conceptionally analysed by animal testing; secondly, combined therapies will be intensively tested; and thirdly, the redox mechanisms in the plasma-toxic action on tumour cells and the effects on immune cells are explored.

Within the scope of the approved animal testing project subcutaneous tumours are directly treated with plasma with different gas admixtures. In that context, the question of which gas admixtures, i.e. which radicals in the plasma are causing tumour toxicity. In the second project, plasma-deactivated tumour cells will be injected to animals with later administration of living tumour cells. In case that growth of the live tumour cells in the animal does not take place, this might be indicative of an immunising effect of plasma on tumour cells. For the purpose of the animal tests we have access to a bioluminescence imager with which the growth of tumour cells in living animals can be determined.

Regardless of the type of cancer, combined therapies in oncology are a silver lining on the horizon of therapeutic success. In addition to surgical resection they mainly consist of chemotherapies and immunotherapies. We have previously had successful results in exploring combined treatment of plasma with mitochondrial modulators and classic chemotherapies, such as Doxorubicin. By screening of concise substance libraries we intend to do further research on highly effective therapeutics in combination with plasma. During guest studies at the University Clinic in Erlangen, combination effects of physical plasma and radiotherapy in melanoma cells will also be analysed.

The molecular provcesses in tumour cells directly after plasma treatment have hardly been analysed so far. By means of fluorescence-based redox sensors that are introduced into cells by a vector system, the plasma-induced oxidation patterns in cancer cells are to be broken down by laser scanning microscope analyses with both locus and time resolution. The role of redox proteins in plasma-induced deactivation of tumour cells will also be explored.

With respect to tumour immunology, we want to gain understanding on the sequences that present tumour cells to the immune cells. This is a decisive aspect for the success of an immune response targeted towards tumours. Many tumour types block immune responses and/or trigger certain immune cells to do so. We want to analyse to which extent this immunosuppression can be interrupted by treatment with physical plasma. For that purpose, the characteristics of immunosuppressive molecules on the tumour cells and immune cells are analysed using patient material, among others.



Anaesthetised mouse with injected tumour on its flank; the tumour cells produce an enzyme that makes the extent of the tumour growth visible in the living animal by means of photon quantification. Consequently, precise monitoring of tumour growth is possible.

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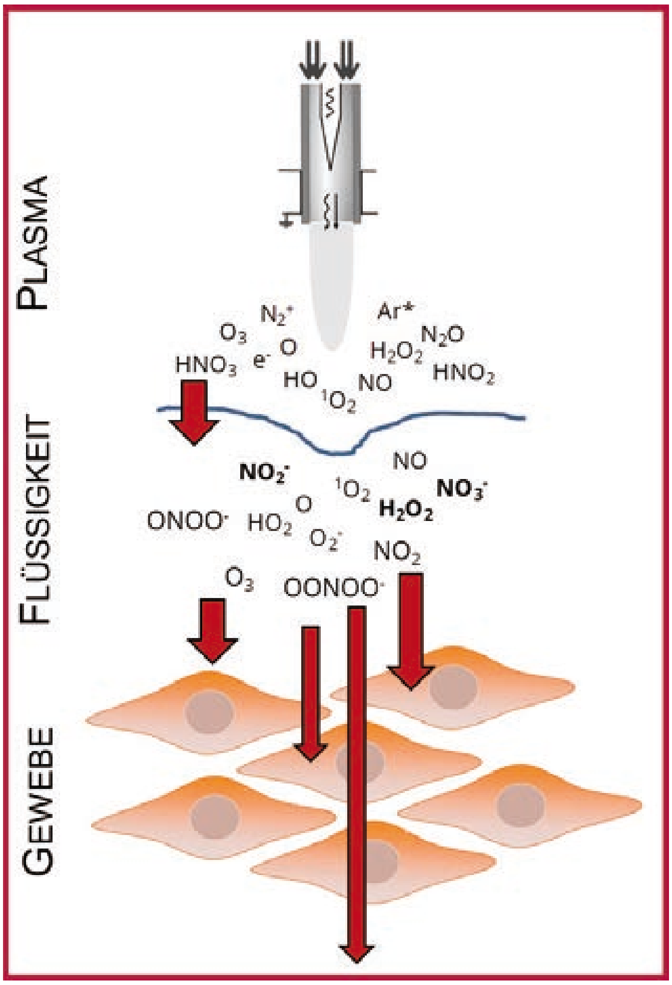
# ZIK plasmatis – plasma liquid effects

The junior research group for plasma liquid effects intends to examine the following question: Can individual redox-active species mainly responsible for special biological effects be identified through detailed analysis of the interaction of cold plasma with liquids and/or tissues?

For this purpose, the chemical processes in aqueous systems triggered by plasma treatment need to be better understood in their full complexity. Biochemical analytics of liquids and biomolecules is in the focus of this work. In this way, the major reactive species deposited in liquid biological systems by means of plasma are to be identified in collaboration with plasma and gaseous phase diagnostics. Together with the "plasma redox effects" research group the functional consequences of the occurrence of such species on human or animal tissue shall also be examined. This includes identification of the major characteristics required for generation of a custom-made "cocktail" of active plasma species for a desired application.

Cold plasmas are increasingly used in clinical applications, such as chronic wounds, infections of the pharynx and malignant diseases. Other fields of application, e.g. psoriasis, are currently being examined. The feature that all these diseases have in common is the occurrence of inflammatory processes and the essential role of the immune system. The biochemical processes taking place during such diseases and appropriate treatment have not yet been fully explored; however, the effects of reactive oxygen and nitrogen species (ROS / RNS) play a decisive role. These compositions are embedded in the most varied signal transduction processes of cells and tissue (redox signalling), for example in NF-?B (nuclear factor "kappa-light-chain-enhancer" of activated B-cells) and related signal paths, such as the WNT signal path (wingless/int-1), the MAPK signal path (mitogen activated protein kinsais), the Keap1-Nrf2 signal path (Kelch-like ECH-associated protein 1 / nuclear factor (erythroid-derived-2)-like 2) as well as the ubiquitin/proteasome system (UPS). In all these protein signalling chains post-translational modification (PTMs) of biomolecules play a role, e.g. through oxidation of protein-related thiol groups or through nitrosylation of cysteine or aromatic amino acids and lipids. Depending on the type of molecule, this will result in either loss of function or gain of function and subsequent influence on enzyme activities. By means of feedback loops and reductive processes (peroxiredoxines, thioredoxines, glutathione) the signal is eliminated again. The free concentration of the important messenger substance H202 does not intracellularly exceed the 10nM mark and superoxide and the RNS peroxide nitrite or NO are subject to strict compartmentation and regulation of their concentrations. Consequently, it is possible for the cell to decidedly and precisely react to changes in the concentrations of ROS/RNS. The cellular processes modulated by these species range from the cell cycle and cell cleavage to cell maturation and cell aging to cell migration. In case of failure of the redox signalling process, pathological processes will take place, such as excessive growth and premature cell aging, among others.

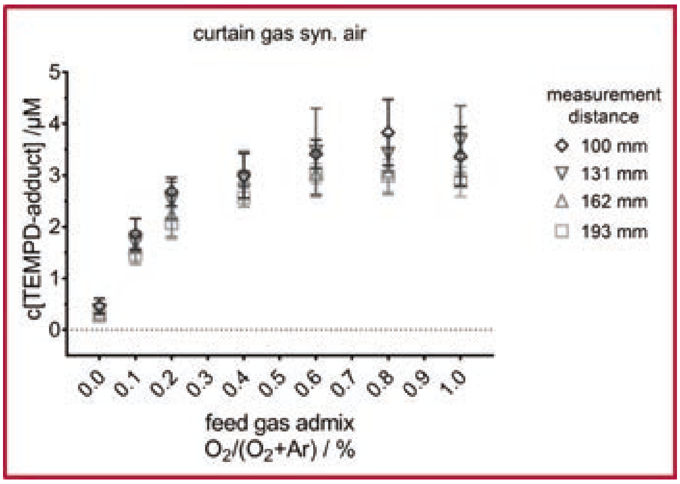



While we have a thorough understanding of the composition of the gaseous phase of cold plasmas, transport of the reactive species through the bordering layer to the liquid and onwards into the cell/tissue require more in-depth analysis. This task is performed by the ZIK-PFE group.

Cold plasmas produce a large number of reactive species, such as ions and excited status of the carrier gas, free electrons and ionic or neutral status of hetero atoms, and/or molecules generated thereof. These include various status of oxygen, such as atomic O, superoxide anion radical, singulet oxygen and ozone, where molecular oxygen is either present in the form of an admixture or laterally ingresses into the effluent. While we have great knowledge about its distribution in the gaseous phase due to simulations and FTIR measurements, the role of its liquids is still unclear. To gain better understanding of this aspect, a range of diagnostics have been implemented in collaboration with international partners, electron-spin resonance (H. Jablonowski, INP), absorption spectroscopy of the gaseous phase (H. Jablonowski/INP and Joao Sousa/LPPG Paris Sud), and the liquid (H. Jablonowski/Alec Wright & Felipe Iza, Loughborough University), as well as emission spectroscopy.

We were able to demonstrate that upon admixture of oxygen to the working gas and an oxygen coat around the jet in the far field (≥ 100 mm to 224 mm) ozone is dominantly present in the gaseous phase and in the liquid. Even if nitrogen is used for the gas coat around the effluent, this is still the case in attenuated manner. Singulet oxygen is only present in case of the nitrogen coat and the concentration of the gaseous phase is dependent on the distance, in contrast to the ozone. In the liquid (physiological buffer) that was treated with a far field of the jet (> 100 mm), significant distance-dependent increase of the EPR signal could accordingly be measured by means of TEMPD (2,2,6,6-tetramenthyl-1-piperidinyl), which is indicative of the presence of ozone. This was confirmed by the Pittsburgh Green colourant developed in Loughborough. However, if the buffer was treated at short distance (9 mm), ozone was not relevant and the EPR signal revealed congruency with the singulet oxygen emission.

Especially upon use of the nitrogen curtain, the significant increase of the EPR signal was linked to the solution of singulet oxygen in the liquid. Further experiments for proof of this phenomenon need to be performed. However, there is a possibility of the TEMP signal in the liquid being caused by atomic oxygen, in addition to 1O2 and O3. Its efficiency in biological systems could be demonstrated in cooperation with Peter Bruggeman (University of Minnesota) on the one hand, and again by Bekeschus/Wende/Benedikt (Kiel University). The ZIK-PFE group is currently performing experiments by the use of chemical tracers to verify these results.




Electron-spin measurement of ozone in physiological liquids. Depending on the admixture of oxygen to the working gas and independent of the distance (> 100 mm) there is a significant increase in the TEMP signal. By measurement using a specific colourant, the presence of ozone could be confirmed under these conditions.

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# Bio Sensing Surfaces

The junior research group for bio sensing surfaces focuses on the development and characterisation of novelty function layers for sensor in the field of life science (e.g. medicine, pharmacy, and biotechnology).

Today, biosensors are used in a variety of applications; for example, in the clinical-medical area for regulation of the blood glucose level, for quality control of food or in environmental analytics for verification of chemicals that are potentially detrimental to the environment. The core of every biosensor is the biological identification structure that may consist of an enzyme, an antibody, DNA or entire cells.

The junior research group assumed their work during the second half of 2017 and examines the generation of electrically conductive polymer coats within an interdisciplinary field of research at the interface of polymer chemistry, material science and plasma technology.

Another priority of their work is coupling of molecules/enzymes/proteins/cells that can be implemented through plasma-based surface modifications. The properties of the thus generated coats are examined using state-of-the-art surface analytics, so that information on the coat structure and stability can be obtained, depending on the coating process. Since these characteristics are in direct correlation with functionalities as biosensoric surface, examinations on the interaction with the analytes are also performed.

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# PLASMA SOURCE CONCEPTS

The "Plasma Source Concepts" research group has emerged from the previous junior research group "Extra-cellular effects". Its work will particularly concentrate on the issue of whether it is possible to design plasma sources that are optimally adjusted to specific medical applications or to develop new concepts for specific applications?

In addition to the experience and the basic principles gained from the "Extra-cellular effects" phase, the technological requirements, such as conception, development and construction of medical plasma sources were particularly considered upon foundation of the group "Plasma Sources". For addressing of the technological tasks, employees from the plasma sources group, who were particularly involved in projects for development of medical plasma sources, were included in this group. The description of the group as spin-off of "Plasma Sources" and integration of "Extra-cellular effects" to become the "Plasma Source Concepts" is very fitting in this case.

The insights in the field of fundamental research now allow for a profound scientific approach for developing new plasma sources that are specifically adjusted to clinical applications and requirements.

The work of the "Plasma Source Concepts" research group is generally aimed at new findings and insights. For example, analyses are going to be carried out with regard to the constituents generated by plasma to modulate the biological processes. In this field, the group directly relies on and interacts with the work of the NWG in ZIK Plasmatis, i.e. "Plasma liquid effects" and "Plasma Redox Effects".

The concept of the "Plasma Source Concepts" research group includes development of novelty source concepts for plasma generation through strategic control of electrons to ensure direct control of the plasma chemistry and new source geometries. For implementation of the intended goals, the group will continue to closely cooperate with the plasma sources department at the INP; recently collaboration with the Diabetes competence centre Karlsburg (KDK) has been taken up.

Moreover, various industrial contacts and projects will be integrated into our work to adapt the concepts to manufacturer's requirements from an early stage.

The fundamental research within the "Plasma Source Concepts" also puts the focus on addressing electrical field measurement, which represents a critical parameter within the "plasma cocktail" of effective species that has not yet been examined. To properly quantify the plasma sources with regard to their efficiency, definition and control of all effective components is intended. In this context, particularly ion density measurement and definition of the electrical field component have been found to be insufficiently addressed.

To measure and understand the component of electrical field strength, various approaches have been investigated. In addition to purchasing a commercial device, which, however, resulted in a number of technical problems, a network of scientific contacts has been built up. Joint tests have been carried out in collaboration with the work group of J. M. Puvesle and E. Robert at the GREMI in Orleans.

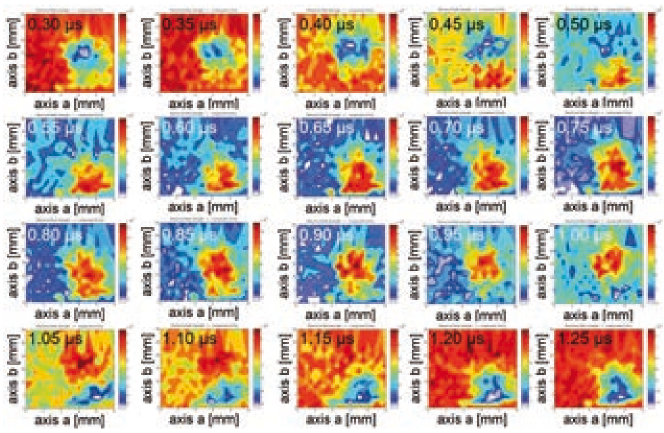


Figure 1: Distribution of the relative electrical field strength in 50 ns; step-by-step within the period of the kINPen 09, measured using a commercial field probe. The jet was placed at the bottom in the middle and the pictures show 2D sections along the effluent. The absolute values may deviate due to a fault in the device.

Moreover, in cooperation with Prof. Dr. Ronny Brandenburg at the INP and M. M. Kuraica from Belgrade, Serbia, the strong polarisation spectroscopy was applied to develop alternatives to the commercial device. In the field of plasma wound healing, a pilot test has been recently initiated to switch off the electric field in connection with the KDK for wound healing.

Other aspects of fundamental research are definition of the power fed into the device for process control and better comparability of individual treatment types and sessions. A master thesis has been dedicated to the topic of interaction of plasma with surfaces as an accompanying work to this regard. Within the framework of the thesis it has been examined how plasma sources adapt to the surfaces of various dielectrics and how that can influence power coupling in some cases.

In view of application options, the "Plasma Source Concepts" research group integrates various demands from the industry and strategic developments at the INP. The emphasis here is on large-surface plasma sources based on dielectrically impaired discharge and on plasma jet arrays. Other devices used in development are the plasma jets for localised treatment of spots that may be hard to reach. In this context, endoscopic applications as well as dental applications within the complex geometry of the oral cavity need to be mentioned.

For conception and construction of laboratory prototypes the portfolio of options and use of most varied materials is constantly expanded. The new equipment for the KDK laboratory is particularly important for this purpose and helps exploring the topic of precision manufacturing of ceramics from various materials. This also holds great potential for collaboration with the work groups of the other divisions of the INP since it addresses a central element of plasma technology.

Further meetings have been held in view of an exchange with the APMC in South Korea to be able to incorporate international perspectives in the development of plasma sources. Joint projects for global cooperation are currently being initiated.

For the coming years we plan to initiate transfer of the large function prototypes portfolio at the INP to the industry. We are currently discussing this with partners from the industry, which might result in bilateral or supported projects. In this way, adjustment of the plasma sources to various fields of application is intended to be carried out with the assistance from the industry. Research in electrical field measurement will be established and expanded through future scientific projects and collaborations.

Figure 2: Function prototype of a plasma jet array with 8 sequentially or simultaneously igniting effluents.

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# Research group
# Plasma Wound Healing (PWH)

The research group "Plasma Wound Healing" deals with the question: Is the wound-healing effect of cold plasmas dependent on the etiology of the wounds or on the spectrum of microbiological colonization? Furthermore, the individually optimized plasma treatment of the various patients and their specific wounds plays a central role in applied clinical research.

Cold plasmas are complex mixtures of free electrons and ions, UV radiation, visible light, mild heat, and excited species. In particular, the excited oxygen and nitrogen species together with UV radiation and electric fields are responsible for the biological effectiveness of the plasmas. These cold plasmas affect the cellular redox balance and, depending on the composition and duration of treatment, can be adjusted to either stimulate or kill cells. Here, the sensitivities of the treated cells differ greatly - which is due to distinctive anti-oxidative potentials of different cell types, as well as their ability to regenerate. Therefore, cold plasmas are suitable for killing bacteria. Multiresistant bacteria show similar reduction rates as their non-resistant counterpart. On the other side, it could be shown that a balanced plasma treatment of human cells can also lead to their stimulation.

The aim of the research group PWH is the transfer of basic results into the clinical practice of wound treatment. Particular attention is paid to deepening and adapting the research results of the ZIK plasmatis on wound healing by finding differences between human cells and the microorganisms present in the chronic wounds. Molecular differences in radical defence, metabolism and cell repair between human cells of the skin and the immune system or the microorganisms within those wounds will be identified. For this purpose, samples of wound liquids - so-called exudates - are obtained and examined for their cellular as well as soluble components.

For these examinations a close cooperation with the Karlsburg Clinic, as well as the Greifswald University Medical Center was started on as part of the Competence Center Diabetes Karlsburg. The aim is to develop a plasma treatment tailored to the patient or the wound in order to further optimize wound healing with the aid of cold plasmas.

The clinical investigations include detailed analyses of the microorganisms (quantification as well as qualitative determination of individual species). Furthermore, these organisms are also screened for possible antibiotic resistances – which might have an influence on wound healing. The second main pillar is the analysis of messenger substances such as growth factors, cytokines and hormones. But also enzymes with known activities in wound healing like matrix-metallo-proteinases will be part of these investigations. This should provide information about possible repair or inflammatory processes, but also provide information on whether a plasma treatment leads to a stimulation of skin cell proliferation and therefore an improvement of wound healing.

The aim of these investigations is to optimize the individual plasma treatment of patients with chronic wounds. Furthermore, our intension is to find molecular hints why the wounds of the various patients display different progression of healing after a comparable treatment regime.

Plasmabehandlung eines diabetischen Fußes mit chronisch infizierter Wunde

At the beginning detailed microbiological analysis were performed, where chronic wounds from diabetic patients were routinely treated with the kINPen MED® (neoplas tools GmbH) for 30 sec per cm2 with cold plasma. The samples were acquired from May to September 2017, and then further analysed for their microbial load. In total, seven outpatients were selected for this study, who were at different stages of treatment. Patients were usually treated once every two weeks. Swab samples of the wound exudates were taken before and after the plasma treatment. The fresh samples were serially diluted and plated using a spiral plater on six agar types: Columbia agar (CBA with 5% sheep blood, SB) for total aerobic bacteria, Schaedler agar (SBA with 5% SB) for total anaerobic bacteria, Columbia CNA agar (CNA with 5% SB) for Gram-positive bacteria, MacConkey agar (MCA) for Gram-negative bacteria, Candida chromogenic agar (CCA) with chloramphenicol and Sabouraud glucose agar (SGA) with penicillin and streptomycin for fungi. Besides SGA (aerobic at 30 ° C), CBA, CNA, MCA, CCA (aerobic) and CBA (anaerobic) were cultured at 37 ° C. After 1 to 2 days of incubation with the bacteria derived from the samples and 5-7 days in the case of fungi, colony-forming units (CFU) were determined per ml of medium. After quantification, colonies were isolated from each agar, purified and then cryopreserved. The resulting cultures were identified by MALDI-TOF mass spectrometry at the certified laboratory of IMD Greifswald.

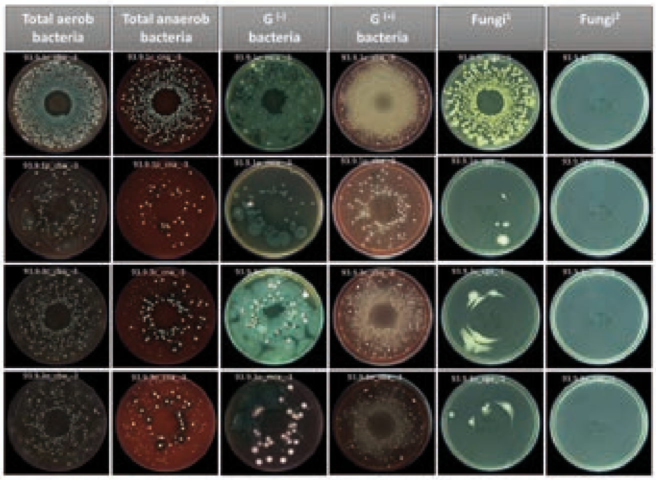
## Results

After macroscopic observation no fungi could be detected on both types of agar. Apart from Gram-positive bacteria, Gram-negative, total aerobic and anaerobic bacteria decreased significantly after plasma treatment. A total of 31 bacterial species belonging to 19 different genera were identified, and three cultures could be identified at the genus level. Ten most frequently isolated species were Proteus mirabilis, S. aureus, P. aeruginosa, E. coli, Klebsiella oxytoca, Streptococcus agalactiae, Enterococcus faecalis, Serratia marcescens, Enterobacter cloacae and Citrobacter koseri (ordered by frequency).

The plasma treatment can significantly reduce the number of most of the bacteria found in this study. In the time between treatments, regardless of their species, the bacteria multiplied again and reached approximately the initial number. Thus, the reduction of the bacterial burden of wounds seems to play only a minor role in healing. For despite the permanent repopulation, a reduction in wound size and improvement in the overall well-being of patients was observed.

## Outlook

Based on these initial results, the bacteria found and identified in the wounds should be analysed for possible antibiotic resistance. At the same time, the strains, which could still be cultivated at the end of the treatment periods, will be tested for possible molecular adaptations. For this purpose, selected strains should be repeatedly treated with plasma after different time intervals in order to subsequently detect the causes of this adaptation by means of sequencing and transcriptome analysis.




Beispielhafte Darstellung der mikrobiellen Analyse der Wundabstriche auf Selektiv-Agar.

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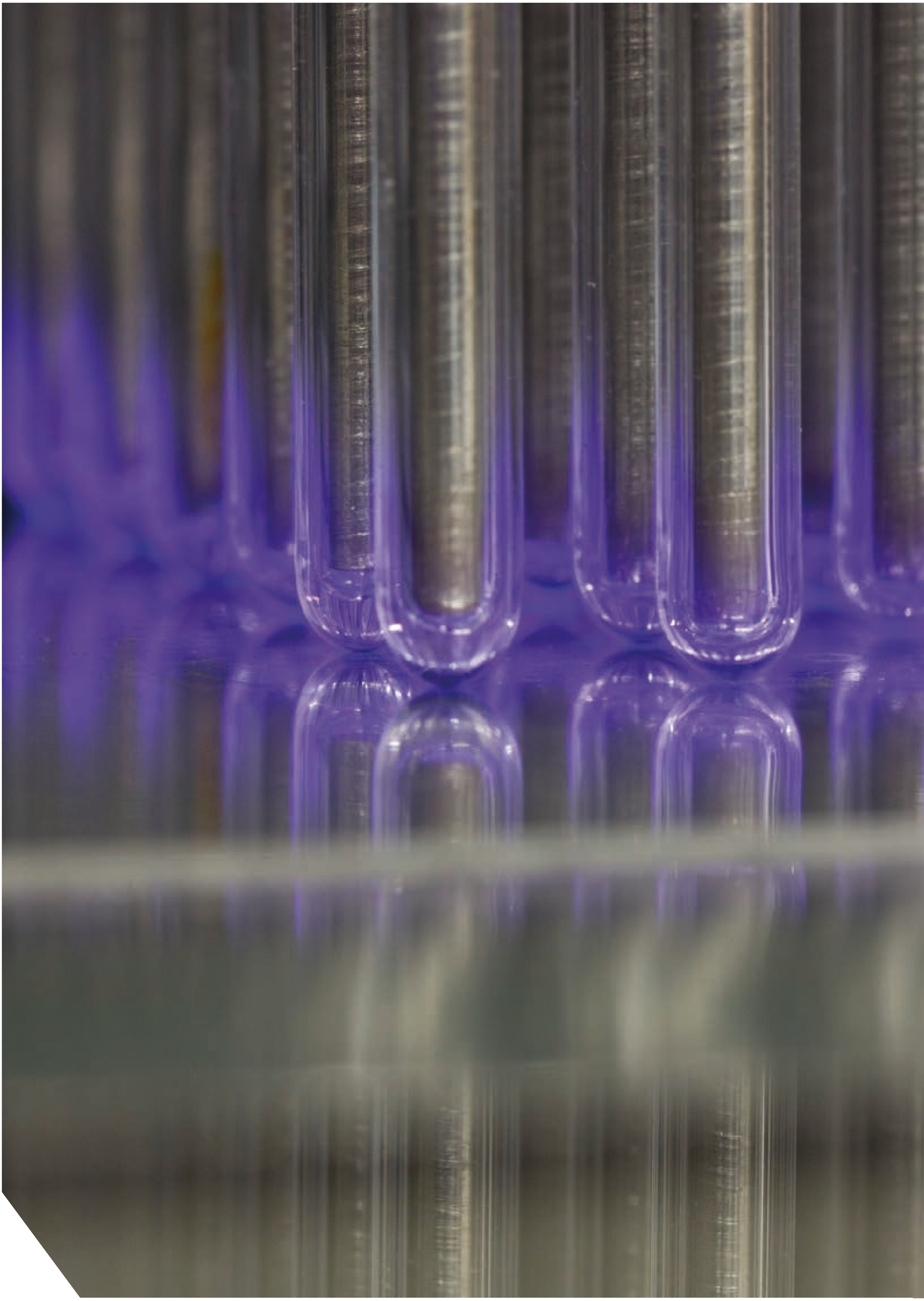
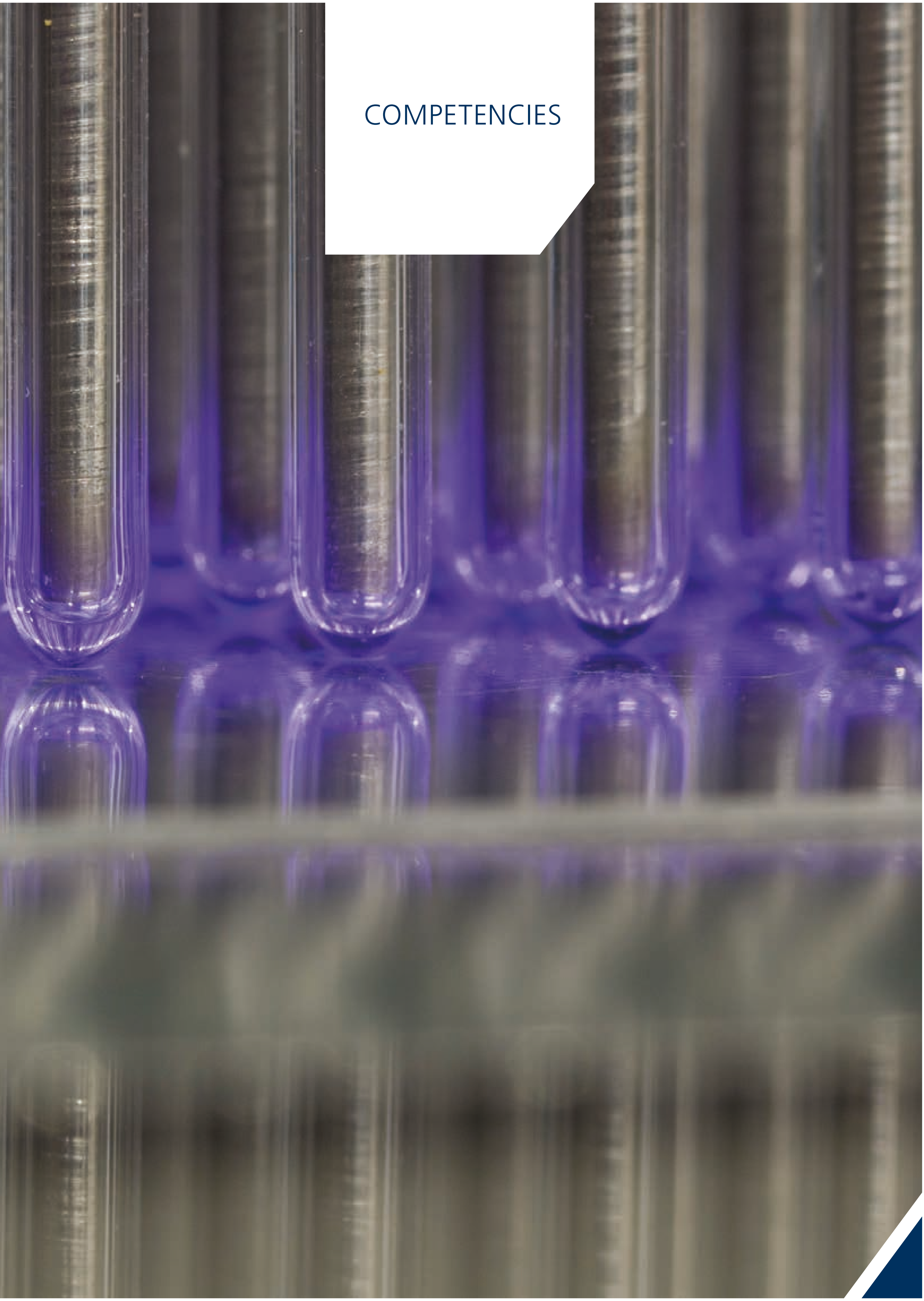


# COMPETENCIES



# Plasma Bioengineering

The department of Plasma Bioengineering pools the competencies in the development of processes that are based on the interaction of plasma with biological materials. We provide expertise in both development, adjustment and diagnostics of plasma sources optimised for the specific tasks and in diagnostics of the treated biological system. Moreover, deduction and optimisation of the required process development is another focus of our work.

The current topical emphasis is on development of plasma processes for hygienisation in the field of post harvesting with a focus on the food industry and on innovative methods for process analysis and monitoring.

Examples for the current activities in the plasma biotechnology department are:

- Development of a hygienisation process based on reactive nitrogen species (RNS) that ensures both dry and wet treatment by means of a basic device.
- Development of optical sensors for process monitoring based on special diode laser systems.

The application-oriented research work is mainly done on the basis of cooperation projects with a major input by the industry.

## Technological equipment

**Single Stage PLexc (SSP)**
Single-stage self-igniting atmospheric microwave-regulated plasma torch for RNS process gas generation (Plasma Processed Air – PPA) with process control for operation of peripheral devices, capacity: 12 slm

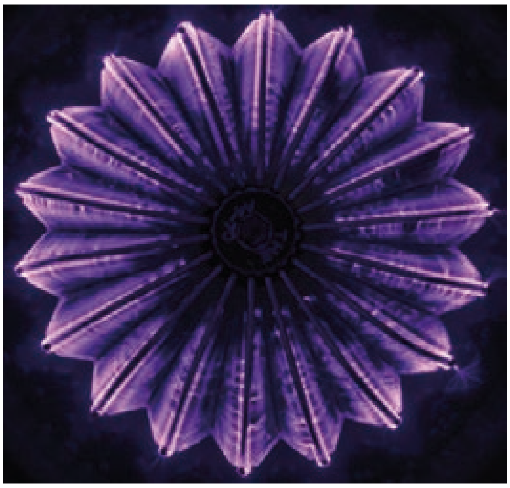
**Auxiliary Decontamination Unit (ADU)**
Dual-stage, self-igniting, atmospheric microwave-regulated plasma torch for RNS process gas generation (Plasma Processed Air – PPA) with process control for operation of peripheral devices, capacity: 100 slm

**Basic Research PLexc (BRP)**
Dual-stage, self-igniting atmospheric microwave-regulated plasma torch for RNS process gas generation (Plasma Processed Air – EPA) with process control for investigation of fundamental process management issues, equipped with various measurement technologies (see below).

**Units for generation of plasma processed water (PPW)**
Total capacity: 2000 l

**Various peripheral devices for dry and wet treatment,** e.g. of bulk goods, fruit and vegetables, as well as, meat products in batches of up to 200 kg

**MinMIP**
Small microwave-excited plasma torch for chemical diagnostics and biological applications



Flexible Electrode Plasma Source (FEPS):
Special plasma source for treatment of eggs
using a flexible electrode system

### Microbiological standard methods
- Proliferation assays
- Life / death determination
- Biofilms
- RG1 and RG2 microorganisms

### Standard methods of quality monitoring
- Water content
- Sugar content
- Colour changes (lab system)

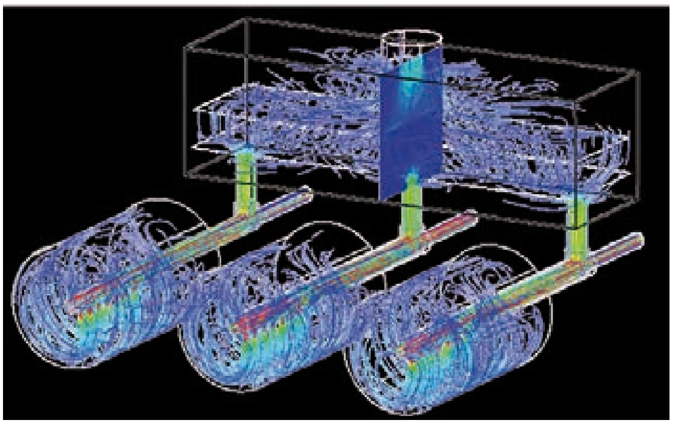
### Optical measurement technology
- Optical emission spectroscopy (OES)
- Fourier-transform infrared spectroscopy (FITR)
- Thermometry
- Laser diode absorption spectroscopy
- Fluorescence microscopy

### High-frequency measuring technology
- Various spectrum and network analysis devices ranging from 10 Hz to 50 GHz
- Microwave interferometer

### High-frequency simulation
Numeric determination of electromagnetic fields and waves, as well as measuring inspection thereof both in 2D and 3D.

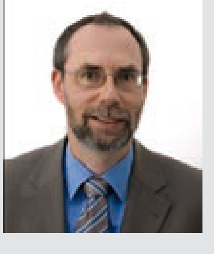
### Flow simulation
Numeric flow simulation based on StarCCM+

### CAD design



Flow simulation of a triple reactor for bulk goods

## CONTACT



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# Plasma Diagnostics

The Department of Plasma Diagnostics works on application-oriented research activities for process monitoring and process control, especially in molecular plasma processes. The research is on basic as well as application-relevant challenges in the field of materials and energy. The focus is on the time- and space-resolved, qualitative and quantitative chemical analysis of molecular plasmas, both in the gas phase and on surfaces.

The Department of Plasma Diagnostics works with state-of-the-art methods and constantly expands the existing expertise as well as the range of instrumentation and methods, in particular in the area of laser-based plasma diagnostics. Addressed spectroscopic problems are in the spectral range from ultraviolet to terahertz.

The application of modern methods of plasma diagnostics is the key to understanding complex plasmas. In particular, a number of interesting and useful properties characterizes molecular plasmas containing a wide variety of different species. The resulting wide range of technological applications ranges from resource-saving surface treatments, for example in the semiconductor industry, to disinfection and sterilization processes, waste gas purification and gas scrubbing, particulate removal as well as the treatment of water, air and hazardous waste.

Plasma diagnostics allow the absolute measurement of energy and temperature distributions as well as densities of stable and transient species in plasma by means of probe diagnostics, absorption spectroscopy and optical emission spectroscopy, thus enabling determination and elucidation of all relevant chemical processes.

In addition to the characterization of plasma processes to answer basic and application-relevant questions, the department also develops and uses diagnostic methods for monitoring and controlling of technological plasma processes. Transfer projects, such as the Leibniz Association sponsored SAW VIP-USD Transfer project, aim at the commercial exploitation of resonator-based absorption spectroscopy with quantum cascade lasers. Based on a validated demonstrator (RES-Q-Trace) developed as part of a BMBF-funded VIP project, a new device class for research and industry is being introduced in the form of a prototype of a compact, portable, ultrasensitive (ppt-sensitivity) trace gas sensor. Potential applications include, for example, the monitoring of technological processes, the monitoring of pollutant emissions, breath analysis and the detection of hazardous substances.

RES-Q-Trace - Demonstrator of a cavity-enhanced quantum cascade laser based trace gas sensor for highly sensitive trace gas sensing.

For the investigations, specially equipped laboratories for the diagnostics of laboratory scale chemical plasma processes with state-of-the-art instrumentation are available.

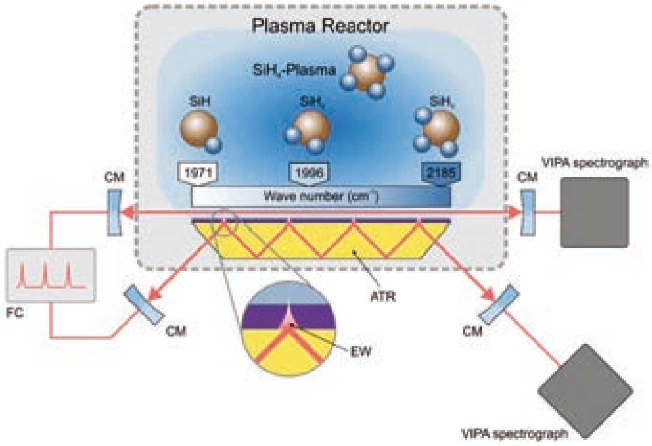
The following methods are applied for the quantitative determination of important parameters such as the species densities and their temperatures, the energy distribution of charged particles as well as for the characterization of all relevant chemical reaction paths:

Laser-induced fluorescence and absorption spectroscopy with coherent light sources in the spectral ranges:

- Laser-induced fluorescence and absorption spectroscopy with coherent light sources in the spectral ranges:
  -- UV-VIS: pulsed dye laser
  -- Mid-IR: diode lasers, quantum cascade lasers, interband cascade lasers, lead salt lasers, frequency comb laser systems
  -- THz: quantum cascade laser
- Optical cavity based laser spectroscopy (cavity ring-down spectroscopy, cavity-enhanced absorption spectroscopy, optical feedback cavity-enhanced absorption spectroscopy and cavity-enhanced attenuated total reflectance spectroscopy)
- Absorption spectroscopy with non-coherent light sources (FTIR spectroscopy from VIS to mid-IR)
- Optical emission spectroscopy (UV-VIS: grating spectrographs with CCD and iCCD cameras)
- Probe diagnostics (Langmuir probe also suitable for time-resolved measurements)
- Mass spectrometry (quadrupole up to 200 amu)

The diagnostic methods are also suitable for mobile use and can therefore be employed for external measurements at the customer.

The first-time use of state-of-the-art frequency comb systems (FCs) in the mid-infrared spectral region will open up a completely new way to elucidate plasma-surface interactions. FCs are to be used as radiation sources in broadband, cavity-enhanced, direct frequency comb spectroscopy (CE-DFCS). This method will allow the simultaneous detection of a large group of transient reactive species in the immediate vicinity of the surface.



Schematic illustration of a combined gas phase and plasma-surface interface diagnostics using CE-DFCS.

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# Plasma Life Science

The department of Plasma Life Science investigates the effects of cold atmospheric plasma on microorganisms, eukaryotic cells and tissue. In doing so, we focus on the therapeutic application and the antimicrobial efficacy.
In addition, there are novel research topics testing atmospheric plasma sources on microalgae for applications in biopharmaceutical uses. While antimicrobial properties of cold plasma are tested in a variety of environments such as liquids or surfaces, the cell biology part deals with modulation of cell metabolism by cold plasma. Taken together, our research concomitants clinical therapeutic applications and aims towards opening new applications. Moreover, new plasma sources are subjected to standardised test procedures in order to evaluate their biological efficacy and antimicrobial activity.

## Techniques/Equipment

### Microbiology:

The laboratories are equipped with well-established test systems for investigating cultivable microorganisms on all sorts of environment (liquid or solid). This includes a spiral plater, several sterile clean benches as well as a photometer for accessing optical densities and a fluorescence microscope. The lab hosts a vast collection of test stems of microorganisms and fungi. New plasma sources can be installed within the lab and if necessary be connected to the gas supply of the institute. The range of methods includes also ion chromatography and HPLC for liquid analyses.

### Pulsed electric fields:

There is expertise and equipment to investigate the effects of pulsed electric fields on biological systems, particularly in cultured cells.

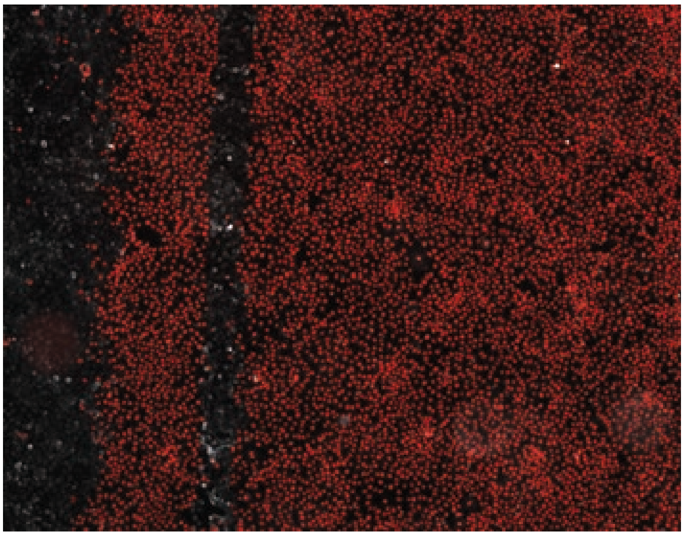
For this purpose an electroporator including a cell stand for the generation of electrical pulses in the range of microseconds to seconds exists.

For the generation of electrical pulses in the range of microseconds to seconds an electroporator including a cell stand exists.

Furthermore, there are pulse generators in Blumlein configuration, which deliver electrical pulses in the range of several nanoseconds. Suspended cells are preferably placed in electroporation cuvettes while adherent monolayer cells can be treated with a special electrode system in multiwell plates. The subsequent examination of the cells includes common cell and molecular biological assays as well as evidence of electroporation by means of fluorescent dyes.

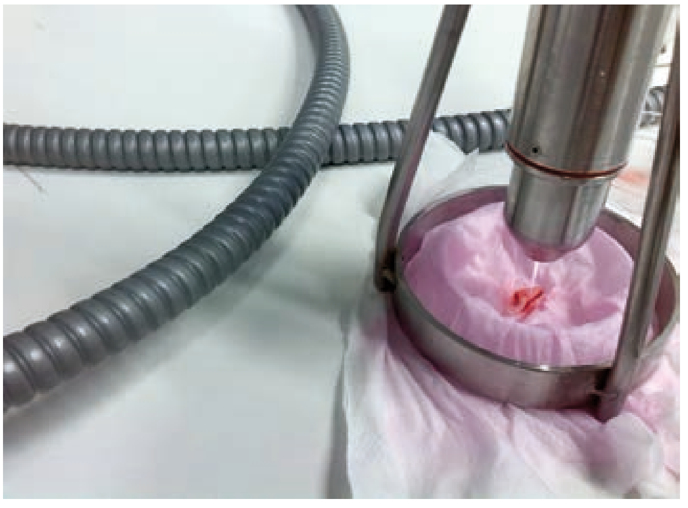
### Protein detection:

Cell metabolism and regulation of protein expression under the influence of cold atmospheric plasma are the subject of research. The laboratories are equipped for Western blots using a membrane transfer system as well as a high-throughput capillary based system. In addition, various other standard methods of protein detection are available such as Elisa or photometric assays. For the investigation of protein-protein interactions surface plasmon resonance spectroscopy is available.



Monolayer of WB-F344 cells 5 min after treatment with pulsed electric field (8x100 µs, 1.5 kV/cm). When the cell membrane is perforated red fluorescent dye is absorbed by the cells as shown on the right side of the image.

The cells on the left hand side are untreated and will not absorb the red fluorescent dye. Evidence of electroporation by means of fluorescent dyes.



Plasma treatment of a tissue biopsy. The kINPen is fixed by a spacer.

### Genetic engineering:

There is expertise and equipment for in vitro genetic engineering at security levels S1 and S2. Non-viral and adenoviral gene transfer systems are generated for a number of different projects. Transfer of genes for overexpression or inhibition (siRNA) elucidate candidate target genes for therapeutic employment. These may be relevant in the treatment of acute and chronic wounds as well as various tumours (e.g. skin tumours). Non-viral gene transfer systems have a transient (temporary) effect in cell culture systems. However, adenoviral vectors are currently the most efficient gene transfer system due to their high transduction rates, especially in vivo. The transferred gene product is expressed for up to three months. In addition, quantitative real time PCR and global microarray analyses add to the range of methods.

### Histology:

There is expertise and equipment for performing histological analyses. Based on a tight cooperation with clinical partners we are in a position to perform close to patient research and to accompany clinical applications. Excised tissue samples can be sectioned by means of a cryostat or a microtome. Subsequently, immunohistochemical or immunofluorescence staining can be employed to visualise targets of interest in situ. These techniques are also in use for animal studies that are realized through co-operations.

### Microscopy:

There are several microscopes available ranging from fluorescence microscope to confocal laser scanning microscope. Furthermore, atomic force microscopy (AFM) to determine the mechanical properties of a sample with high resolution also on living cells is available. With this technique, elasticity of cells can be determined. Scanning electron microscopy provides high resolution imaging.

### Outlook:

The available methods and expertise work excellently in combination and supplement each other. This opportunity offers a multitude of further possibilities that will be extended even more in the future.

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# Plasma Modelling

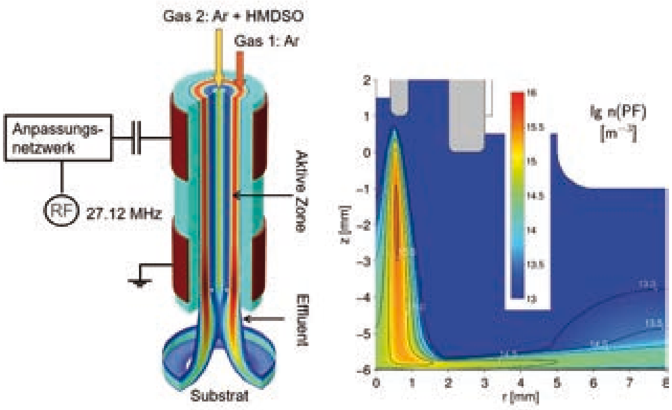
Modelling of plasma sources and plasma reactors plays a central role in the field of plasma research and plasma technology. Based on extensive parameter studies, model calculations and simulations enable the specific optimization of technological plasmas as well as the development of new applications. The performance of cost-intensive and time-consuming experiments can be reduced by means of modelling. In addition, model calculations and simulations allow the determination of parameters, which cannot or are difficult to be measured, and thus make the analysis of their behaviour possible.

At INP Greifswald models and simulations are predominantly developed and applied for the technological and scientific utilization potential of non-thermal plasmas at low and atmospheric pressure. The spectrum of models extends from the description of individual plasma effects to the complete modelling of plasma sources and plasma processes. In this regard, the focus is currently on plasma sources for surface modification and for energy and environmental applications, on plasma processes for the degradation or conversion of pollutants, as well as on arc plasmas for welding, cutting and switching. Furthermore, solutions for the management of research data are worked out that should enable an improved subsequent use of the interdisciplinary results of the plasma technology.

The modelling of such plasmas requires in each case (i) the development of an appropriate plasma model, (ii) the formulation of hydrodynamic and/or kinetic equations for the species of the plasma, (iii) appropriate equations for the electric (and magnetic) field, (iv) the research and evaluation of atomic data, (v) the problem-specific development of appropriate numerical methods and the usage of commercial codes, respectively, to solve the resulting system of ordinary and partial differential equations, (vi) the systematic determination of solutions for selected parameter ranges, as well as (vii) the visualization and scientific interpretation of the results.

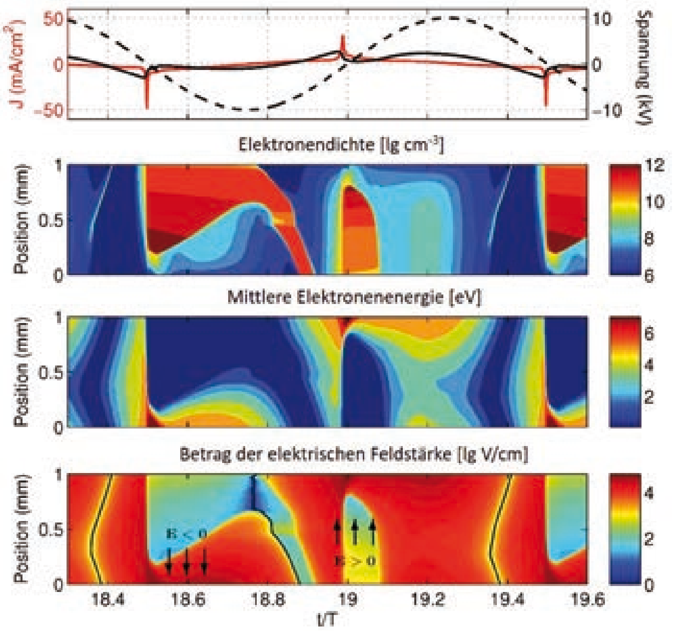
The complexity of the complete description of plasma applications necessitates that partial problems, such as the kinetic description of electrons and ions, the plasma-chemical modelling of reactive plasmas and the treatment of radiation transport, are treated separately.

The description and analysis of the weakly ionized plasmas takes place by means of both numerical methods developed at INP and commercial software packages. The problem-specifically adapted methods of INP are characterized by high efficiency, stability, and accuracy. They have been partly verified by means of  benchmark comparison. The model calculations and plasma simulations are carried out on modern clusters, whose availability has made the theoretical description of the complex, multi-dimensional problems possible in the first place. The investigations are usually performed in close connection with experimental works and funded projects at INP as well as in cooperation with national and international partners from research institutions and industry.




Non-thermal atmospheric-pressure plasma jet for the local deposition of thin films and calculated particle density of neutral precursor fragments (PF) in the effluent

The focus of the scientific department is on the realistic description and analysis of the properties and the behaviour of scientifically and technologically relevant low-temperature plasmas in the medium term. In addition to the currently studied plasma applications in the INP's research programmes Materials/Surfaces, Plasma Chemical Processes, Welding/Switching and Decontamination, plasmas for plasma-medical applications will be increasingly analysed in the future. The investigations of the different low-temperature plasmas allow in particular for a deeper physical understanding and the quantitativ determination of (i) the temporal and spatial variation of the densities of individual plasma components, (ii) the energy dissipation due to collision and radiative processes, (iii) the particle and energy transport processes in the plasma, (iv) the electric (and magnetic) fields occurring in the plasma, and (v) the interation of individual species with walls, electrodes and organic components.




Hydrodynamic modelling of the discharge dynamics of a dielectric barrier discharge for the $CO_2$ dissociation

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# Plasma Surface Technology

The department for plasma surface technology bundles years of experience in development of plasma-assisted processes for modification of surfaces for applications in the high-tech sector, e.g. automotive, aerospace, optics, microelectronics and tool sector, as well as in the life science sector, e.g. implants, biosensors, food industry or biomedical products.

Using plasma technology it is possible to selectively modify nearly any surface property, and in this manner generate a new generation of material surfaces with special functions.

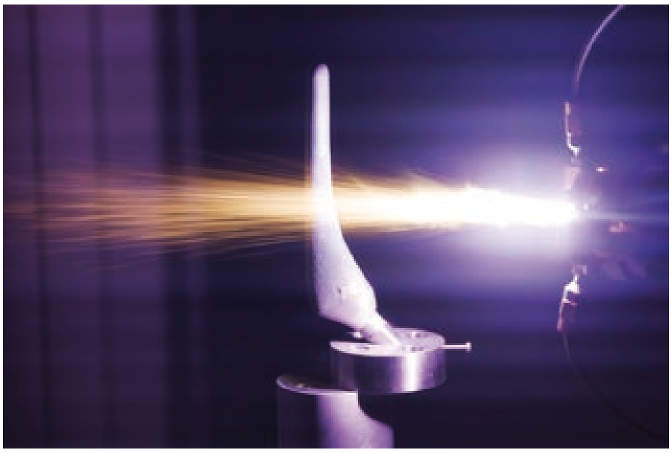
The expertise includes

- Modification of metal, ceramic, glass and plastic surfaces
- Process development for deposition of optical coatings
- Surfaces with photo-catalytic effect
- Scratch resistant surfaces
- Wear protection
- Corrosion and oxidation protection
- Hydrophilic/hydrophobic surfaces
- Biocompatible surfaces
- Cell adhesive/cell-anti-adhesive surfaces
- Antimicrobial surfaces
- Textile treatment
- Development of atmospheric pressure plasma sources for layer deposition
- Plasma fine cleaning
- Plasma-based polishing, deburring, and cleaning of conductive materials
- Surface-finish of 3D-printed surfaces

## Technological equipment

Different plasma processes under low pressure and atmospharic pressure conditions are used and under continuous development. Equipment in laboratory as well as industrial scale is available for this.

- Processes in DC, DC-pulsed, high-frequency, and microwave plasmas
- Atomic Layer Deposition (ALD)
- Ion implantation (PIII and PIII&D)
- Magnetron sputtering
- High power impulse magnetron sputtering (HiPIMS)
- Plasma spraying
- Plasma polishing
- Plasma ion-assisted deposition (PIAD)
- Plasma-enhanced chemical vapor deposition (PECVD)
- Surface modification via atmospheric pressure discharges (DBD, plasma jet)



Application of plasma spraying for coating an implant

Surface analysis is one of the special areas of INP Greifswald. The existing spectrum of diagnostics, the operation skills, as well as the methodology for evaluating the measured data are continuously under enhancement and improvement.

Analysis of topography and morphology
- High-resolution scanning electron microscopy (HR-SEM)
- Scanning transmission electron microscopy (STEM)
- Atomic force microscopy (AFM)
- Profilometry
- White light interferometry
- Light microscopy with 3D function

Determination of chemical composition, bonds and structures
- High resolution x-ray photoelectron spectroscopy (XPS)
- Energy-dispersive x-ray spectroscopy (EDX)
- X-ray diffractometry (XRD)
- FTIR spectroscopy

Determination of wear resistance
- Abrasion test
- Calotte grinding method

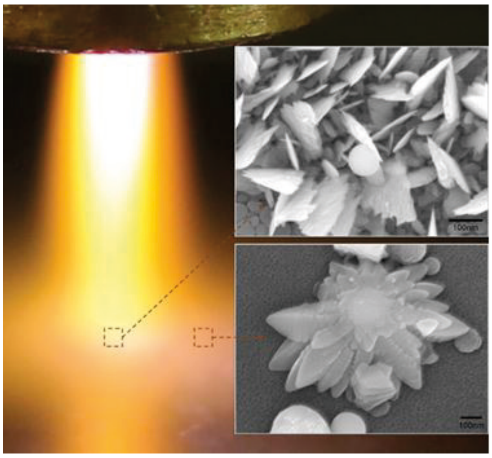
Examination of mechanical properties
- Microindenters
- Nanoindenters
- Taber test

Determination of contact angles and surface energy
- Contact angle measurement devices

Determination of optical properties
- UV-VIS spectralphotometry
- Optical ellipsometry

The capability of materials for different applications depends on the significantly surface properties. Therefore, new developments at the INP Greifswald are intended for the following purposes, among others:

- Surface finish of 3D-printed workpieces
- Plasma-polishing of conductive surfaces
- Development of modern plasma processes for atmospheric-pressure layer deposition
- Coating of plastics by means of high-rate deposition processes (plasma spraying)
- Smart coating of materials in view of industry 4.0



Deposition of a nanostructured copper oxide layer by a non-thermal atmospheric pressure plasma source

## CONTACT

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# Plasma Process Technology

The expertise of the plasma process technology department consists of the development of plasma-aided synthesis methods for depositing of nano-dimensional metal, metal-oxide and graphitic particles and thin layers. For this, synthesis methods PVD processes (physical vapour deposition) such as magnetron sputtering, plasma ion assisted deposition, plasma propyrolysis and PECVD procedures (plasma enhanced chemical vapour deposition), as well as their combinations are used. In addition to these vacuum-based methods, plasma processes in liquids are also used for generation of carbon or graphene-containing materials, as well as metal-oxide and metal nano-particles. Within the framework of joint planning together with other research departments at INP, in future the plasma process technology department will direct its focus on developments for staff and technical equipment through PiL. We also develop and build up our expertise on plasma-catalytic processes using CO2 as raw material.

The main fields of application for the plasma processes developed in our department are catalytic surfaces, materials for energy storage/conversion, particularly components for hydrogen technologies, sensor technology, chemical synthesis, as well as water or gas purification and processing. Here plasma technology offers a variety of approaches to implement large scale application of nanotechnology in this field. A number of application-oriented projects is currently being carried out e.g. in development of synthesis methods for platinum- or nickel-based catalysts, as well as graphene- and metal oxide-based electrode and membrane components and in plasma-chemical bonding of catalysts on substrates. Extensive equipment for characterization of the nanostructure, morphology, crystal structure, porosity, chemical composition, optical, electrochemical and photochemical properties is available for development of efficient function elements.

## Experimental equipment

**Plasma technology, PVD, PECVD:**

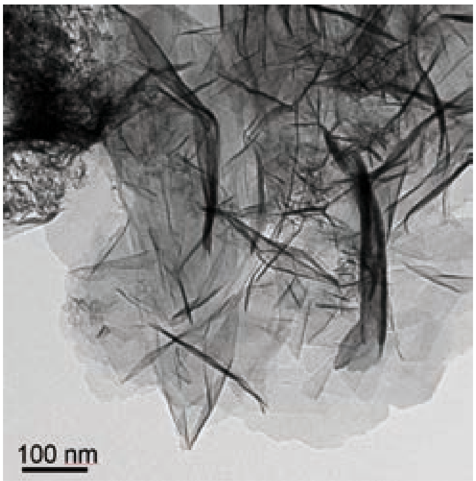
- Six vacuum receiving tanks with 2 and 3 plasma sources for deposition of
  - Metal oxide layers, e.g. semiconducting layers such as TiO2, WO3
  - Carbon-metal nano hybrid layers, e.g.: C-Pt
  - Metal-metal nano hybrid layers, e.g. Pt-Co
  - Metal/metal oxide polymer composite layers e.g.: Co2O3 HMDSO plasma/plasma polymers
  - Metal-polymer complex layers, e.g.: co-polypyrol
- PIAD vacuum-coating system, M 900

**Plasma technology powder modification**

- Rotary drum reactor, HF excitation or
- Microwave excitation, vacuum process: Activation or coating (PECVD) of bulk goods
- Downer reactor, microwave excitation, vacuum process: Pyrolysis of bulk goods

**Plasma technology synthesis of nano particles:**

- Plasmas in liquids, pulse discharges, e.g.: synthesis of nano-scaled graphene-supported metal oxide particles




Graphene (plasma in liquid process)

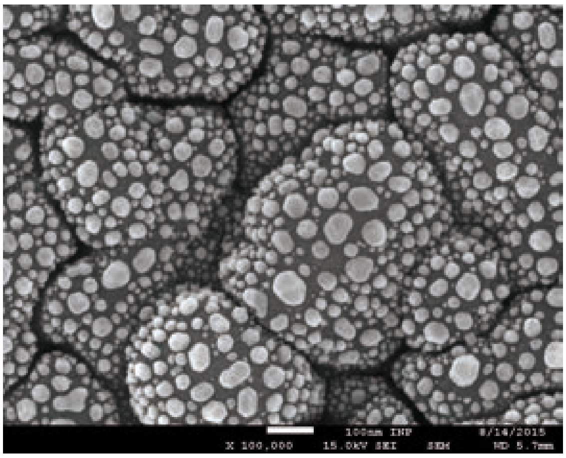
**Characterisation of nano structure, morphology, crystal structure, molecule structure, porosity:**

- Keyence digital microscope: 2D and 3D photos of up to 1000x magnification
- BET sorption measurement, Quantachrome NOVA 2000: determination of the specific surface of solids through nitrogen adsorption.
- FTIR spectrometer: Bruker VERTEX 70v: digital FTIR vacuum spectrometer for measurements in the MIR range (8000 to 350 cm-1) and FIR range (600 to 50 cm-1)
- MasterSizer 2000 by Malvern Instruments: measurements of grain size distribution in powders in the range from 20 nm to 2 mm
- Bruker D8 Advance x-ray diffractometer with high-resolution LYNXEYE detector: X-ray diffractometry (XRD) on polycrystalline layers and powders for identification of crystal phases and crystal size determination. X-ray reflectometry (XRR) for determination of layer thickness and roughness. Rietveld analysis
- Scanning electron microscopy/EDX, Joel (Germany) GmbH, in addition transverse-section polisher, IB-09010CP, Joel (Germany) GmbH: transverse-section polishing device for generating ultra-smooth surfaces that cannot be mechanically polished.

**Characterisation of optical, electrochemical and photochemical properties:**

- PerkinElmer Lambda 850 UV/Vis Spectrophotometer with L6020322 150 mm integrated sphere measurement of transmission, scatter and reflection
- µ-Autolab 2 potentiostat, electrochemical measurements
- Autolab Bipotentiostat 302N, electrochemical activity measurements
- ATV in-line-4-point probe with Keithley 2400 Sourcemeter, measurement of the specific electrical resistance of surfaces and thin layers
- Im6e potentiostat, Zahner GmbH, electrochemical characterization
- PCS photoelectrochemical Photo Current Spectra System, Zahner GmbH, photoelectrochemical measurement
- CIMPS Fast Light Intensity Transient System, Zahner GmbH, photochemical measurement
- COLT Coating and Laminate Tester, Zahner GmbH, AC-DC-AC tests on coatings and laminations

**Outlook on future focus areas:**
A focal point of the department's expertise will continue to be in the field of generation of various materials and material combinations with the help of PVD and PECVD with a topical orientation towards renewable energies. Within this scope the subject of synthesis "Plasmas in liquids" is going to be developed further and applied more and more often. Another emphasis is on atmospheric pressure plasma sources for energy storage by means of synthesis of hydrocarbons using $CO_2$.




Gold nanoparticles on a $TiO_2$ layer (sputter process)

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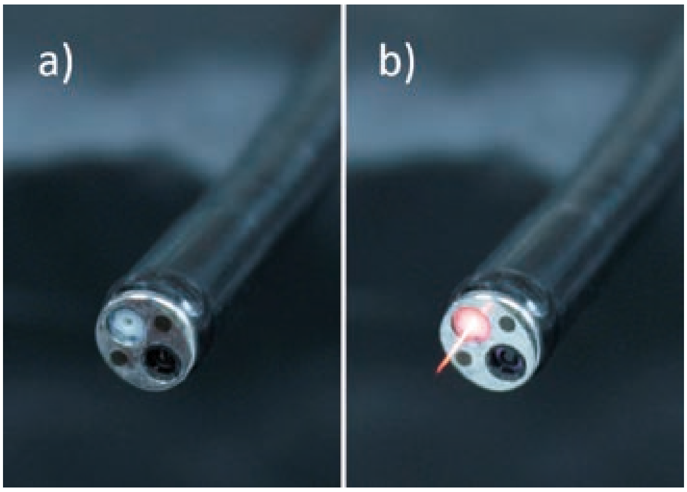
# Plasma sources

Development and characterisation of atmospheric pressure plasmas is a core competence of INP Greifswald. Various methods and systems are developed depending on the specific application and customer requirements. Precise characterization of the sources and basic knowledge of plasma parameters and processes makes it possible for us to selectively design new processes, or optimize existing technologies.

The objective of our activities is research and development of integrated atmospheric pressure plasma systems as new production tools, or for use in environmental technology and the healthcare sector. For these tasks, the INP has special laboratories in which plasma sources can be designed and created or characterized via plasma diagnostics. Moreover, the activities are supported through an extensive research infrastructure of the entire institute, which in addition to state-of-the-art methods of plasma diagnostics, also offers a microbiological laboratory, a cell culture laboratory, plasma chemical analysis, environmental monitoring systems, and diagnostics for surface properties and material properties.




Generation of a plasma jet at the distal end of an endoscope; a) plasma off, b) plasma on

We are able to efficiently evaluate the biological effects of new plasma source concepts without having to deal with long and error-prone wait periods and distances, particularly due to the close proximity of the biological laboratories. This is especially beneficial for development of new contamination processes.

The research infrastructure is supplemented by rapid prototyping technologies, e.g. 3D printing, stereo lithography and laser cutting. This allows for fast and flexible development of novelty plasma source concepts which enables us to react to feasibility enquiries from project partners from industry and science in a clear and timely manner.

The core activities and the technical equipment of the plasma sources department are listed below:

## Plasma source development

### Medical plasma sources

- Design and set-up of problem-adapted plasma sources, e.g. for surface treatment, plasma medicine, decontamination
- Analysis of parameters that require approval/certification, such as irradiance and discharge currents
- Consideration of legal requirements already during the development stage (e.g. medical products act)
- Development of control software
- Support of clinical partners

### Technical plasma sources

- Plasma source and process development for room air hygiene, exhaust gas treatment and plasma-chemical synthesis
- Development of plasma sources for reduction of contaminations in water (e.g. pharmaceutical residues)

### Pulsed power technology

- Design and set-up of pulsed high-voltage supplies for pulsed plasmas and pulsed electrical fields (bioelectrics)
- Electrical measurement technology for characterization of pulsed high-voltage signals

## Analytics and production processes

**Gas phase analytics**

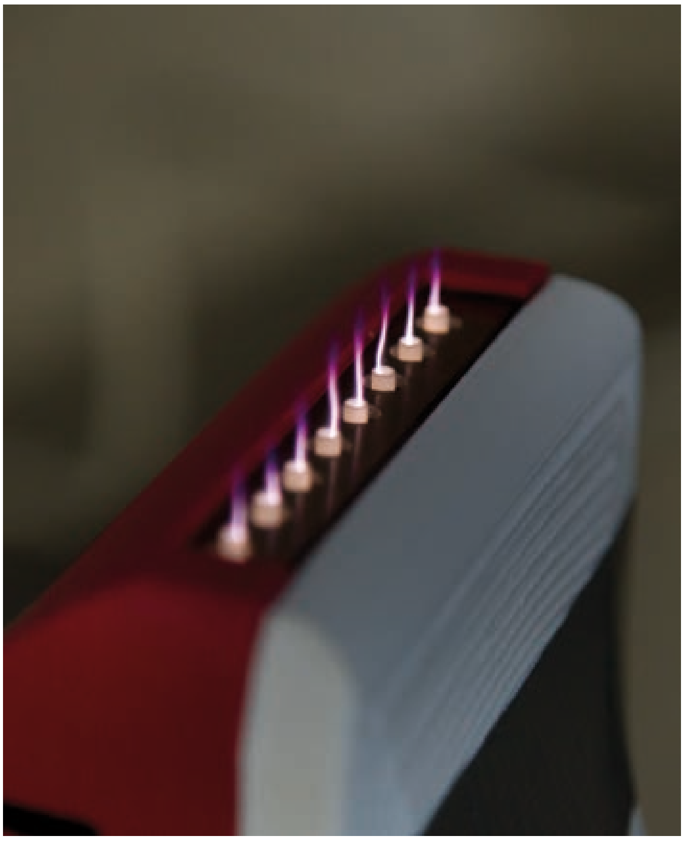
- Highly sensitive and specific gas analysis (FTIR, GC, GC/MS, FID) for verification of plasma-generated reactive species (e.g. h2O2, NOx, O3) down to ppb range
- Characterization and simulation of gas-phase chemistry in plasmas
- Optical emissions spectroscopy from infrared to VUV spectral range
- Imaging processes (ICCD camera, framing camera)
- Time-correlated single photon counting with time resolution in the sub-nanosecond range
- Extensive electrical measurement technology
- Field trials with mobile gas analysis equipment

**Liquid analytics**

- Verification of chemical substances in liquids (GC, HPLC)
- Basic analysis and characterization of plasma-treated liquids (in cooperation with the liquid diagnostics laboratory at INP)

**Rapid prototyping process**

- 3D printing (printing of complex geometries from various materials, in particular:
  - Laser melting system (3D production of metal objects)
  - FDM (Ultimaker, coarse resolution)
  - FDM (Prusa I3, MK3, medium resolution, various materials can be simultaneously printed)
  - SLA (stereo lithography process, very fine resolution, gas- and water-resistant printing possible)
  - Laser cutter (for fast and reproducible cutting of stainless steel 2-3mm, quartz glass and plexiglass)



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# Plasma Radiation Technology

The department deals with the experimental analysis of thermal and non-thermal plasmas in electrical engineering (high-current, high voltage technology, switching applications) and process engineering (welding and cutting engineering) by means of electrical, optical and spectroscopic diagnostics for the purpose of quantitative analysis.

Current research topics are the study of welding arcs, of high-pressure wall-stabilized arcs and of vacuum arcs in circuit breakers and surge arrestors as well as of plasma phenomena in high-voltage insulation systems.

The further development of methods of high-speed imaging linked with optical emission and absorption spectroscopy supports the improved accessibility of plasma properties and deeper understanding of basic mechanisms both in fundamental research and in applications.

An increase of sensitivity and spatial resolution of optical methods, expansion of applicability for the cold regions near to the surface of electrodes, the accessibility and characterization of spatially non-symmetric plasma phenomena with high dynamics, the robustness against distortions in real-life applications, as well as mobile and flexible use are paramount.

Besides quantification of local properties in the arc, determination of surface temperatures and other properties for example of electrodes in different arc applications are of interest. In addition, application-specific non-invasive sensor and control systems are proposed based on the expertise in laboratory diagnostics. The department has the corresponding equipment of welding engineering, high-current and high-voltage engineering as well as vacuum equipment at one's disposal, beside state-of-the-art diagnostic systems.

View of the  arc research laboratory: Impulse current generator (on the left), vacuum chamber with pumping system and drive (on the right)

## Technological equipment

### Arc research laboratory

- Experimental setup for studies on high-current arcs:
- Impulse current generators with variable wave forms (AC of variable frequency 16-1000 Hz, pulsed DC, lightning pulse, superimposed wave forms)
- Vacuum chamber for studies on high-current vacuum arcs
- Electrical and optical diagnostics

### Welding  laboratory

- Experimental setup with fixed welding torch holders and moveable test specimen, including gas supply, exhaust system and radiation protection
- Power sources of various manufacturers, as well as a freely programmable source
- Electrical and optical diagnostics

### High-voltage laboratory

- HV generators for AC up to 100 kV, DC up to 130 kV, pulsed voltage up to 135 kV
- Partial discharge diagnostics (conventionally as per IEC 60270, frequency response analysis, acoustic sensors, UHF sensors, measurement of the dielectric response of resistance measuring devices

### High-current laboratory

- Continuous current test setups (max. 3000 A)
- Climate Laboratory with climate chamber for cooling and warming cycles (-70 - +180°C), and programmable ovens (+250°C)
- Thermographic camera
- Thermal probes
- Resistance measuring devices (nΩ to µΩ)

### Photometric laboratory

- Test setups with suitable power generators for simulating of realistic lamp operation
- Integrating sphere (also known as Ulbricht sphere)
- Compact spectrometers
- Luminance camera
- Optical calibration sources

### Equipment for optical measurements

- The following equipment for optical measurements is available to all laboratories:
- Mobile and stationary equipment for imaging optical emissions spectroscopy and optical absorption spectroscopy
- High speed cameras, framing camera, streak camera
- Equipment for thermography / pyrometry
- X-ray computer tomography for non-destructive diagnostics of electrodes or material samples.

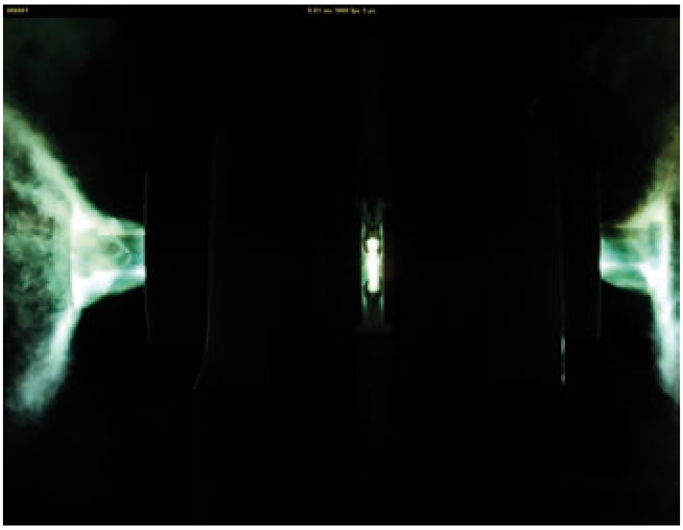
### Future priorities

Characterization of the plasma-boundary layers, such as plasma-wall and plasma-electrode interaction requires further adaption of the quantitative diagnostic methods for application on cold periphery and expansion of the pool of devices within the department. Temperature measurement ranging from room temperature to some thousands of Kelvin are our objective to enable studies on cooling dynamics of welded and switching contacts and analysis of their energy balance.

Adjustment of the high-power generator in the arc research laboratory for higher currents and extension of the system by an additional high-power module is intended to ensure continuation of the research work subsequent to medium voltage circuit breakers and studies on the properties of switching arcs under realistic conditions.

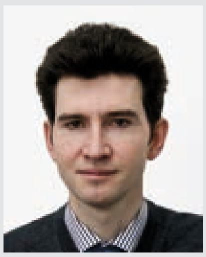
Development of non-conventional methods for state diagnostics of high-voltage apparatus, for example optical diagnostic methods, is another direction.

Increase of the applicability of absorption spectroscopy through use of laser-based systems, e.g. acoustic-optical modulator-controlled diode laser, ensures identification of the properties of highly dynamic objects, i.e. of ablation dominated arcs, vacuum arcs and welding arcs, among others. Direct measurement of particle densities and determination of gas temperatures ensure quantitative characterization of thermal non-equilibrium plasmas.



High speed camera image of an ablation dominated arc in $CO_2$

## CONTACT



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# Management support – research management

Modern research institutions demand for professional research management. Therefore, the INP Greifswald established a separate department, the "Management Support" (Stab) in 2007. In matters that involve research strategy and patent issues the Board of Directors, the Heads of the Research Divisions and the Heads of the Research Programmes consult the Management Support. The department has the task of advising and supporting INP scientists in raising external funds. In this regard, the Management Support provides information on new funding regulations, and it assumes co-responsibility for preparing project proposals. Moreover, the department supports transfer of technology and knowledge, as well as process management. In addition to executing its own projects, the Management Support is also responsible for external communications.

## Research funding

About half of the budget of the INP is third party funds competitively received from federal and state ministries, European Union, DFG, and Industry. The Management Support department supports the scientific departments with acquiring third-party funds, identifies suitable funding programmes on local, regional, national and international level, and checks internally the eligibility of project ideas. The department assists the scientists with preparing and submitting project proposals, in particular with creating and formulating project ideas, preparing plans for resources, schedule and work, designing budget plans and considering funding politics. The Management Support acts from the point of view of funding agencies, and contributes to raise the quality of INP project proposals.

## Public relations

The "Management Support" is responsible for the external communication and organises events and marketing activities of the INP. In the area of public relations the department distributes press releases, is in touch with journalists, takes care of visitors, organises events and designs INPs print and online contents, for instance promotional material, the institute's website, and social media channels.

Regularly the INP hosts national and international conferences, symposia, workshops, and networking events. Here, the Management Support assists in planning, organizing, and implementing. We design and plan the institute's appearance at external events, e.g. industrial shows, and provide support for preparation and assistance during the events. Our work in the area of graphic design covers the conception, design and production of our print and digital media – from corporate design, via flyer, brochures, graphical animation, and illustrations and graphics for publications, we offer our scientists a broad spectrum.

The overall strategy is a targeted communication to our stakeholders in the fields of industry, science, politics, and society – and communication with our students.

## Industrial property rights

The aim of the INP is to exploit its research results to products and/or technologies for the use in industry, or to transfer the results via spin-off companies. To support this, the position of patent manager is part of the Management Support department. The patent manager is responsible all issues regarding intellectual property and inventions (patents, utility models, trademarks) in close cooperation with the inventors at INP and external patent law offices. In addition, the patent manager organizes and heads the monthly meetings of the patent-board, the main decision-making body regarding IP rights and its strategy at INP. The patent-board consist of the Chairman of the Board of Directors and scientific director, the financial director, and the head of the Management Support department.

## Project coordination

The Management Support takes care for coordination of large-scale projects by providing a project coordinator. These coordinators serve as contact between the scientists, the INP administration and the respective funding agencies. The main tasks of the coordinator are to prepare decision documents regarding budget planning and controlling the projects resources, to organize meetings of the project boards and scientific workshops, and to design the external representation. The coordinator ensures regular communication between the project staff member, builds up networks to industry and research institutions and prepares reports. In doing so, large-scale projects are optimal assisted and supported.

# Management & Infrastructure

## Knowledge and technology transfer

The institute's motto – FROM IDEA TO PROTOTYPE – outlines both the statutory mission to both conduct application-oriented fundamental research and utilize the respective research results.

INP Greifswald carries out projects from public research funding to increase the knowledge for socially relevant topics. The results of these projects are continuously published by the institute in peer-reviewed journals, at national and international conferences and at events for the general public. For application-relevant topics of economic interest, INP Greifswald contributes his knowledge in terms of a service provider for customer solutions. These mostly bilateral industrial projects help our business partners to benefit directly from the most recent knowledge of the research at INP.
As the first institute of the Leibniz Association ever, INP founded for its own company for the purpose of its technology transfer: neoplas GmbH (www.neoplas.eu). It acts as the second part of the three-stage model developed by the institute. According to the motto "FROM PROTOTYPE TO PRODUCT", future pilot customers are involved in the development work, for example.

If certain utilization activities prove to be economically viable, they may lead to further spin-offs. Knowledge, which is economically exploitable and shall initially not be offered as costumer solution, could be developed up to market readiness in a new spin-off that way: "FROM PRODUCT TO MARKET".

As a major addition and for organizational support of the divisions and departments the “Management & Infrastructure” department was founded at the INP. Its main task is to organize and ensure smooth operation of the company while fulfilling the criteria for lean operation in both fields, management and infrastructure.

The Management & Infrastructure department of the institute includes 5 subject areas – HR, finance/controlling (including procurement, accounting, system and external resources management, travel costs and electronic laboratory), infrastructure, and the IT/EDP section. The infrastructure subject area consists of the mechanical workshop, a glass blowing workshop and is responsible for building services engineering of the institute, as well as any required constructional measures. For the purpose of data processing, the INP operates and expands a data network, and maintains connection of the INP network to external networks.

To comply with the occupational health and safety requirements and the applicable safety standards, specific competent persons (for hazardous materials, fire protection, electrical safety, radiation protection, data protection, laser safety, biological safety) have been appointed. Coordination of their activities is carried out by the safety officer, who is entitled by the Board to issue instructions.

# APPLICATION LABORATORIES

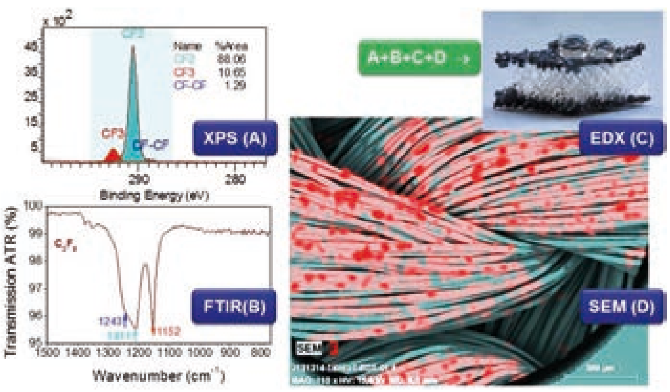
# Laboratory for surface diagnostics

The properties of materials and the interaction of materials with the environment are primarily determined by surface conditions. By using plasma technology it is possible to specifically modify almost any surface property and to generate new materials with special functions that way. The analysis of surfaces is one of the areas of expertise of the INP Greifswald. The existing spectrum of diagnostic devices, the knowledge for operation and the methods for analysing measurement data are continuously extended and improved.

### Analysis of topography and morphology
- High-resolution scanning electron microscopy (HR-SEM)
- Transmission scanning electron microscopy (STEM)
- Atomic force microscopy (AFM
- Prolifometry
- White light interferometry
- Light microscope with 3D function

### Determination of the chemical composition and bindings in the surface
- High-resolution X-ray photoelectron spectroscopy (XPS)
- Energy dispersive X-ray spectroscopy (EDX)
- X-ray diffractometry (XRD)
- FT infrared spectroscopy

### Determination of wear resistance
- Abrasion test
- Calotest (calotte grinding)




Correlated examinations (A+B+C+D) ensure application-oriented optimization of the properties of plasma-treated samples. The sample surface was coated with a fluororcarbon plasma polymer.

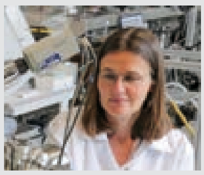
### Examination of mechanical properties
- Microindenter
- Nanoindenter

### Determination of contact angle and surface energy
- Contact angle measuring devices

### Determination of the surface charge of solids
- Zeta potential measuring device

### Determination of optical properties
- UV-Vis spectral photometry
- Optical ellipsometry

## CONTACT



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# Arc research laboratory

The arc research laboratory primarily serves for application-driven research for the increase of reliability and lifetime of switching devices. Therefore, experiments on vacuum arcs and wall-stabilized arcs are utilized to study the arc behaviour and the electrode load in low, medium and high voltage switchgears at different current pulse shapes. Specific electrode arrangements including ablation nozzles can be used to simulate conditions in real switching devices or to study the interaction of the electric arc with electrodes, walls as well as with magnetic fields. The coupling between different optical diagnostics for the physical analysis of the arc is a unique feature of the laboratory. For instance, optical emission spectroscopy allows for the measurement of temperatures and species densities in the electric arc and thus determination of all relevant plasma properties. High-speed imaging techniques is used to study of the dynamics and structure of the arc starting from the arc ignition process. In addition, surface temperatures of the electrodes can be analysed using combined diagnostic methods.

The laboratory equipment includes in particular:

- Setup for the operation of high-current arcs by means of pulsed current generators with the parameters (peak values): sinusoidal current pulses (DAC) up to 80 kA/ 5 ms, 40 kA/ 10 ms, or 25 kA/20 ms, square wave pulses up to 10 kA/ 2 ms or 2kA/10ms, flexible electrode arrangement including actuators for electrode movement
- Vacuum chamber including mounting support for electrodes, pneumatic actuator and access for optical diagnostics and probe measurements
- Electrical and optical sensors (photodiodes) for recording of temporal evolutions of current, voltage and emission signals in specific spectral ranges as well as corresponding methods for their analysis
- 0.5 and 0.75 m spectrographs with intensified CCD cameras (single images with exposure times from few ns to ms) for optical emission spectroscopy
- Thermography / pyrometry for contactless measurement of surface temperatures of e.g. electrodes
- High speed imaging cameras for up to 70000 frames/s for the study of the arc dynamics including spectral selective filters (narrow band MIF, edge filters, polarizer filters), double frame optics for simultaneous recording with two different filters and one camera
- Framing camera (4 independent images within e.g. 5 ns with exposure time of 3 ns) and streak camera (temporal resolution <1 ns, 1 spatial dimension) for the observation of arc ignition processes in the ns-range


Pulsed current generator and vacuum chamber in the arc research laboratory

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# Welding arc laboratory

The laboratory allows for the study and experimental examination of welding arc processes under realistic conditions in practical applications and is equipped with modern measuring techniques, in particular

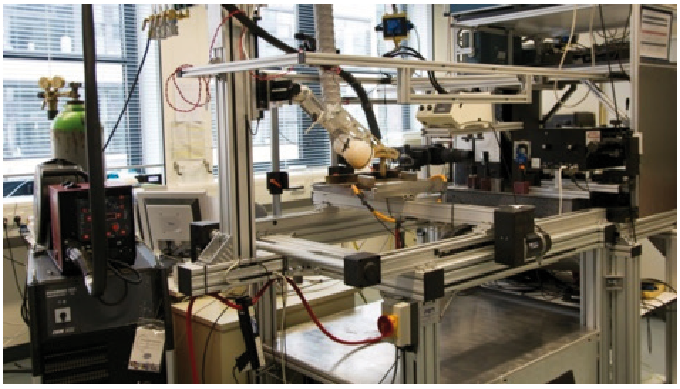
- Setups with fixed mounting of the torch and flexible movement of test workpieces under the torch for the optical process analysis from different viewing angles, e.g. from top, parallel or perpendicular to the substrate surface including gas feed, exhaust unit and radiation protection
- Current sources by different manufacturers (e.g. Fronius CMT advanced 4000R, EWM Phoenix 521 progress pulse coldarc) as well as a freely programmable source (TopCon Quadro)
- Electrical and optical sensors (photodiodes) for recording of time sequences of current, voltage and emission signals in specific spectral ranges as well as corresponding methods for their analysis
- 0.5 and 0.75 m spectrographs with intensified CCD cameras (single images with exposure times from few ns to ms) for optical emission spectroscopy, in particular for measurements with high spatial and spectral resolution in the in spectral range from 300 nm to 900 nm with resolution of up to 0.05 nm
- Framing camera (4 independent images within e.g. 5 ns with exposure time of 3 ns) and Streak camera (temporal resolution <1 ns, 1 spatial dimension) for the observation of arc ignition processes in the ns-range
- Thermography / pyrometry for contactless measurement of surface temperatures of e.g. electrodes
- X-ray computer tomography for non-destructive diagnostics of electrodes and material probes

Most of the measurement setups (spectroscopy, high speed imaging, thermography) are mobile and can be used for external measurement campaigns.

The diagnostic equipment (spectroscopy, high-speed cameras and thermography) may also be used for mobile applications, for example in external measurement set-ups.

The focus of all examinations and studies is on time- and space-resolved analysis of the arc, the arc attachment at the electrodes, the material transfer and the weld pool properties. In addition, the process stability is evaluated and/or quantified by means of optical measurements.

Plasma diagnostics allows for the measurements of temperature and species densities and, on the basis of that, determination of the plasma properties of the welding arc. High-speed imaging techniques is used to study the arc structure, its dynamics and the material transfer. Moreover, surface temperatures of the weld pool and of the metal droplets can be analysed.



Set-up for performance of welding tests with fixed torch position and moving workpieces, in connection with devices for imaging spectroscopy and high-speed cinematography.

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# High-Voltage / High-Current Laboratory

The focus of the application-driven research in the laboratory is put on the increase of reliability and lifetime of electrical components taking in particular into account the aspects of environmental protection and energy efficiency.

The following topics are currently under investigation on in the laboratories for high-current and high-voltage engineering (at the joint professorship at the University of Rostock):

- partial discharge diagnostics and analysis of electrical devices and components
- aging of insulation materials under extreme conditions
- electric contacts and connections (long-term stability, aging, thermal dimensioning and design)
- electric switching contact: optical and spectroscopic analysis of switching functions

The laboratories for high-current and high-voltage analysis are equipped with state-of-the-art measuring and recording devices:

- High-voltage laboratory with digital measuring system including partial discharge measurement (basic noise level <1 pC), for AC voltage up to 100 kV, DC voltage up to 130 kV, impulse voltage 135 kV
- Partial discharge diagnostics with partial discharge analysis system (IEC 60270, UHF), impedance measurement system (35 TΩ, probe voltage 10 kV), dielectric response analyser (200V, 100 µHz ... 5 kHz)
- Climate laboratory with climate chambers for cooling and warm up cycles (-70 - +180 °C), thermo-chambers (+250 °C)
- High-current laboratory with continuous-current setups (max. 3000 A), temperature measurement with thermal sensors as well as IR camera technology

View of the high-voltage laboratory at the joint professorship for high-voltage and high-current engineering at the University of Rostock

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# Microbiological Laboratory

Workstation in the microbiological laboratory

The INP Greifswald has its own microbiological laboratory of the security level 2 according to § 44 IfSG (German Infectious Diseases Protection Act) allowing activities with pathogens in accordance with § 49 IfSG and § 13 BioStoffV (2000/54/EG and 2010/32/EU). Current research activities include phytopathogens and human pathogens of risk groups 1 and 2.

The microorganisms used are:

- Acinetobacter baumannii
- Bacillus atrophaeus endospores
- Candida albicans
- Enterococcus faecium
- Escherichia coli
- Geobacillus stearothermophilus endospores
- Listeria innocua
- Listeria monocytogenes
- Micrococcus luteus
- Pectobacterium carotovorum
- Proteus mirabilis
- Pseudomonas aeruginosa
- Pseudomonas fluorescens
- Pseudomonas marginalis
- Salmonella enterica subsp. enterica Serovar enteritidis
- Salmonella enterica subsp. enterica Serovar typhimurium
- Staphylococcus aureus
- Staphylococcus epidermis

In addition, the institute cooperates with accredited and certified testing laboratories in the field of hygiene and participates in interlaboratory tests within research projects.

The microbiological laboratory performs application-oriented fundamental research and order-based research for cooperation partners form the science and industrial sector for testing of anti-microbial effects of atmospheric pressure plasma sources. Specific and customised adjustment to the test conditions and specimen to the requirements of the plasma sources and devices under test in accordance with the future application is a unique feature of the microbiological laboratories. Work priorities are mainly in the field of testing of anti-microbial plasma effects for treatment of sensitive materials, medical product, food, and agricultural products, as well as examination of plasma sources for treatment of liquids. The range of microbiological methods includes growth tests, anti-microbial sensitivity tests and fluorescence microscopy analyses, among others. For determination of the viable cell count or optical density, a spiral plate system and a spectral photometer are available. Suitable nutrient media and incubators (heat cabinets) can be used for cultivation of microorganisms. In addition, safety workbenches are provided to ensure aseptic performance of tests and examinations.

## CONTACT

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# Laboratory for High-Frequency Engineering

Provision, optimization and development of methods and systems of high-frequency engineering. They are used from the small-signal range for diagnostic applications to the large-signal range for the operation of microwave plasma sources.

The focus is currently on the following systems:

- (frequency-resolved) microwave interferometry power controlled and in free radiating systems up to 150 GHz
- Electron density determination: 1012 – 1022 m-3, Δt < 1 μs
- Determination of permittivity und permeability
- Development and implementation of beam-shaping elements (mirrors and lenses) for the adjustment of Gaussian beam paths up to 150 GHz
- frequency-resolved reflectometry in power controlled and in free radiating systems up to 50 GHz
- Single-port interferometry for the electron density determination
- Adjustment and optimization of methods of the digital signal processing
- Development of microwave components for the manipulation of scattering parameters
- Phase shifter
- Matching networks
- Mode coupler
- Barrier-free reactor access ports
- Development of microwave plasma sources
- Mini-MIP (powers < 100 W)
- Plexc (powers < 1500 W)

The development activities in the listed fields of activity are supported by numerical tools such as Matlab©, Comsol Multiphysics© and CST Microwave Studio©. The results obtained with it can be validated by means of systems for network analysis with a measuring range up to 50 GHz.

Electron density measurement using a 50 GHz intereferometer in a low-pressure plasma discharge area

## CONTACT

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# Laboratory for AOM laser and industrial sensors

The laboratory for AOM lasers and industrial sensors represents the foundation for construction and provision of AOM laser system and/or development and application of measurement methods based thereon. As a basic component of the EasyLAAS measurement system the AOM laser is used in laser absorption measurement for determination of particle densities, electron densities, temperature and pressure in plasmas and as industrial particle density and pressure sensor for technical gasses.

Another field is the development of non-laser-based sensors, which includes an NO2 sensor used for process control of plasma sources and the MiniMip plasma source that can be used as chemical sensor.

The following system are currently predominantly used:

- MiniMip: plasma source that is used together with a gas chromatograph and optical spectrometer; detection limit for mercury: 10^-13 g (100 fg)
- NO2 sensor: high dynamic range: 10 – 10000 ppm
- EasyLAAS/AOM laser: measuring frequencies up to 250 kHz (scans per second); electronic tuning range up to 11 nm (1700 GHz, 56 mc-1); systems for various wave lengths:
  - System 455 nm: particle density measurement up to 10^7 particles/cm³ (with an absorption length of 2 mm)
  - System 1370 nm: contact-free pressure measurement of beverage bottles; measuring interval (incl. evaluation) up to 100 µs; accuracy 50 mbar @ 100 ms averaging time
  - System 770 nm: measurement of oxygen atom densities (5SO, 777 nm) at kINPen in a range of 10^9 1/cm³ in focal multi-path setup; measurement of excited argon density in welding arcs
  - System 770 nm: absolute distance interferometry in the sub-micrometre range
  - System 810 nm + 790 nm: measurement of argon particle densities (10^10 1/cm³), gas temperature (1000 K) and electron densities (10^20 1/cm³) of various plasma sources


EasyLAAS system for laser absorption measurement

With the listed measuring systems, the data collection feature is supplemented by a signal processing unit with special evaluation algorithms adapted to the respective measurement tasks. This ensures very low detection limits, on the one hand, and exploitation of the existing potential up to real-time-capability due to the high scanning speed of the AOM laser, on the other hand.

## CONTACT

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# Laboratory for Plasma Bioengineering

The laboratory for plasma bio process engineering provides the option for availability, optimisation and development of methods, processes and systems for treatment of biological materials using plasma. Depending on the requirements, the projects implement scopes from laboratory to pilot plant scale, both in-house and externally. In this context, one of the focus areas is microwave-excited plasma sources.
The following systems are currently predominantly used:

**Single stage Plexc (SSP)**
Single stage, self-igniting, atmospheric microwave-regulated plasma torch for RNS process gas generation (Plasma Processed Air – PPA) with process control for operation of peripheral devices, capacity: 12 slm

**Auxiliary decontamination unit**
Dual-stage, self-igniting, atmospheric microwave-regulated plasma torch for RNS process gas generation (Plasma Processed Air – PPA) with process control for operation of peripheral devices, capacity: 100 slm

**Basic research PLexc (BRP)**
Dual-stage, self-igniting atmospheric microwave-regulated plasma torch for RNS process gas generation (Plasma Processed Air – EPA) with process control for investigation of fundamental process management issues, equipped with various measurement technologies (see below).

**Units for generation of plasma-processed water (PPW)**
Overall capacity: 2,000 l

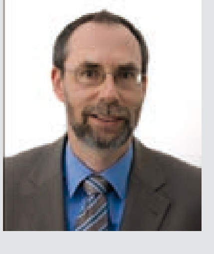
**Various peripheral devices for dry and wet treatment**
e.g. of bulk goods, fruit and vegetables, as well as meat products in batches of up to 200 kg.

**MinMIP**
Small microwave-excited plasma torch for chemical diagnostics and biological applications

Measuring methods:
Mass spectrometry
Fourier transform infrared spectrometry
Fluorescence microscopy
Concentration measurement of nitrogen oxide
Moisture measurement with high time resolution


Microwave-excited process gas generator for biological decontamination of packaging materials and foods

## CONTACT



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**We see ourselves as the leading institution in plasma research and technology in Germany, comprehensively combining basic research and applications.**
Being part of the Leibniz Association, the INP Greifswald is a non-university research institute which focuses on application-oriented basic research in low temperature plasma physics.

## GOOD SCIENTIFIC PRACTICE

**We deliver top performances in science and technology due to good scientific practice.**
Our research is carried out in accordance with the rules for the safeguarding of good scientific practice of the Leibniz Association and the German Research Foundation (DFG). This includes, among other things, consequently following the international state of the art in research and technology and a continuous advancement of scientific methods, a thorough working method, including the ever questioning of own results, esteeming the scientific work of each individual and the promotion of the extensive cooperation.

## STRATEGY

**The realization of long-term goals and sustainable results is the strategy of the institute.**
The institute ensures a creative environment to claim the best possible work conditions for its employees and to open up new perspectives. Future-oriented topics of international relevance that have an impact on society as a whole and, furthermore, high scientific standards, are the focus of our work. It is possible to help shape trends in politics, economics and research on the basis of a substantiated overall strategy.

## EQUAL OPPORTUNITIES

**We offer equal and balanced life- and entrance chances for all.**
The INP supports equal opportunities for men and women as well as for people with a handicap and creates a family friendly work environment. Topics like equal opportunities, no discrimination, family support and compatibility of work and family are an inherent part of the institute's culture on all organizational levels. We see it as our responsibility to secure and live along the lines of these standards.

## COMMUNICATION AND TEAM PLAY

**We are open, fair and respectful to each other.**
We face our partners with appreciation and respect the cultural diversity. Multidisciplinarity and in-house cooperation are the basis of our success. We count on self dependent actions and employee participation, based on the fields of functions defined in the matrix structure.

## JUNIOR STAFF DEVELOPMENT

**We promote and support junior staff on all levels of our institute and even beyond.**
Junior staff development is, in all fields of activity, of particular concern to us in the competition for the best scientific minds. We pique young researchers' interest in topics relevant to society as a whole thanks to our application oriented basic research. We permit concrete experiments in research and in cooperation with industry partners. To us, junior staff development comprises all qualification phases – from school, to university and apprenticeship to professional activities.

## INTERNATIONALIZATION

**We are successfully operating nationally and internationally.**
From Greifswald, we cooperate with worldwide acclaimed research institutes. We support our scientists to seize international exchange opportunities and promote opportunities for international visiting researchers at our institute. The active shaping of the European research area is one of our key aspects.

## TRANSFER OF RESEARCH RESULTS

**The results of our research are socially and economically exploitable.**
Our research is being transferred into concrete applications. This includes publications of scientific results and their transfer into products and services.

## Award for excellent equal opportunities scheme!

**For the second time in a row, the INP Greifswald was awarded with the TOTAL E-QUALITY certificate. After our successful application in 2014, October 2017 was the second time for the institute to receive the popular award.**

The association TOTAL E-QUALITY Deutschland e.V. awards these certificates and thus acknowledges the activities of companies and organisations to enable equal job opportunities for men and women. "The active and well established work for gender equality" as well as "a significant development in the field of equal opportunities" justifies the renewed distinction as the jury stated. This aim is achieved once talent, potential and competence of all genders is appreciated, considered and supported – a high standard in particular for personnel policy. The certificate is valid for 3 years. Thus in 2020 the INP Greifswald can apply again.
The initiative developed that certificate with the assistance of the Federal Ministry for Education and Research (BMBF) and the European Union, and it is awarded for exemplary action in the spirit of personnel management aligned to equal opportunity.

TOTAL E-QUALITY Deutschland e.V. was founded in 1996 in Frankfurt am Main and initially was oriented to commercial enterprises. To date, approximately 250 organizations have been honoured. Since 2001, research institutions and colleges can also compete for the award.


## Work and family life

In a scientific research institute, ambitious and high-quality results can only be delivered by highly motivated employees. They must be supported and fostered by superiors to the best of their professional and personal possibilities and they need the best-possible support by the institute for reconciliation of family and working life.

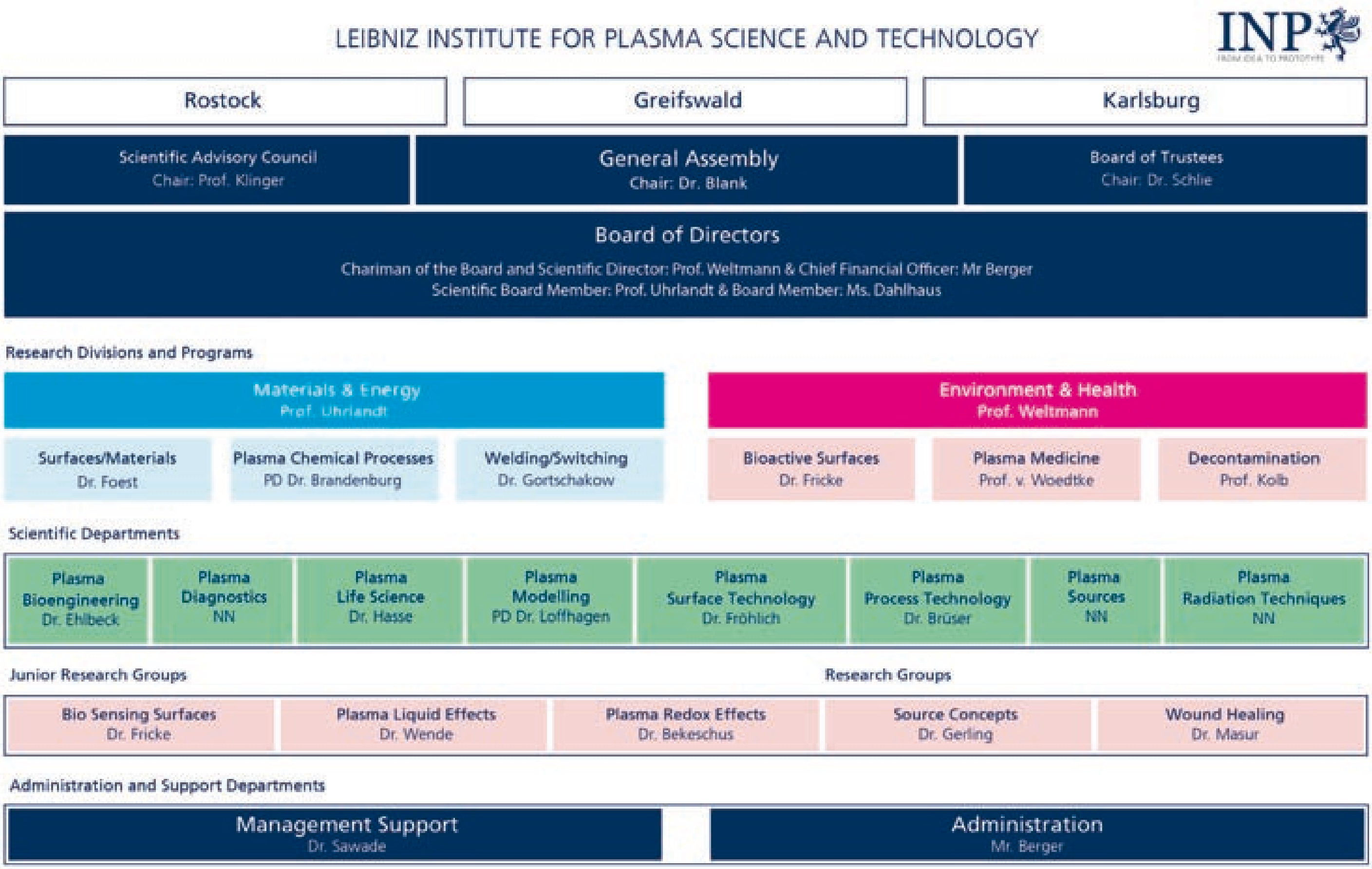
The Leibniz Institute for Plasma Science and Technology e.V. (INP Greifswald) therefore actively engages in equal opportunities of men and women. This is an integral part of the INP's philosophy and is also included in the statutes and the guidelines of the institute. Evidently, this topic is given high priority among the institute's management and executives and they provide considerable support both in strategic equality planning and in implementation of individual activities.

And since good commitment for equality of men and women involves more than quota and regulations, we create and provide concrete family-friendly working conditions. We manage to enthuse the best researchers and scientists of their fields for the INP and ensure long-term loyalty of our employees and their scientific potential for the institute. Our portfolio of offers for our employees ranges from flexible working hour and workplace agreements to a separate parent-child room for parents to bridge gaps in child-care.

We are committed to equal opportunities as well as no-discrimination policies in all levels of the institute and we proactively implement our philosophy by employing people from different nations and with very diverse biographies. We support our employees through individually adapted personal development initiatives that are regularly discussed and designed in joint meetings.

TOTAL E-QUALITY

Certificate for a successfully implemented concept for equal opportunities of men and women, awarded by TOTAL E-QUALITY Deutschland e. V.




## Board of Trustees

The Board of Trustees is the supervisory body of INP including representatives from the State of Mecklenburg-Western Pomerania and the Federal Republic of Germany.

The Board decides on all essential scientific, economic and organizational issues of INP.

### Members (2017)

## Scientific Advisory Council

The Scientific Advisory Council is the advisory body of INP. The members are internationally renowned scientists from university and non-university research and from industry who are active in the research areas of the Institute. The Scientific Advisory Council advises the Board of Trustees and the Board of Directors in all relevant scientific and organizational issues, particularly in long-term research planning.

Members (2017)

**Dr. Uwe Kaltenborn (Vorsitzender)**
HIGHVOLT Prüftechnik Dresden GmbH
Dresden

**Prof. Dr.-Ing. Peter Awakowicz**
Ruhr University Bochum

**Ernst Miklos**
The Linde Group, Unterschleißheim

**Prof. Dr. Dr.-Ing. Jürgen Lademann**
Charité – Medical University Berlin

**Dr. Jean-Michele Pouvesle**
GREMI - Université d'Orleans, France

**Prof. Dr. med. Wolfgang Motz**
Klinikum Karlsburg

**Prof. Dr. Dr. h.c. Manfred Thumm**
Karlsruhe Institute of Technology (KIT)

**Prof. Dr. Satoshi Hamaguchi**
Osaka University - Center for Atomic
and Molecular Technologies (CAMT)

**Prof. Dr. Annemie Bogaerts**
University of Antwerp

**Prof. Dr. rer. nat. habil. Ursula van Rienen**
Faculty for Information Technology
and Electrical Engineering Rostock

**Prof. Dr. Alexander Fridman**
Drexel University

## General Assembly

The General Assembly is the highest decision-making body of INP and elects the Board of Trustees, passes resolutions on amendments to the Statutes, approves the report of the Board of Directors on the status of INP and formally approves the actions of the Board.

Members (2017)

**Dr. Wolfgang Blank (Chair)**
BioTechnikum Greifswald GmbH

**Dr. Benedikt Weiler**
Federal Ministry of Education and Research

**Woldemar Venohr**
Ministry of Mecklenburg - West Pomerania for Education,
Science and Culture

**Prof. Dr. Dagmar Braun**
Braun Beteiligungs GmbH, Greifswald

**Prof. Dr. Holger Fehske**
University of Greifswald

**Dr. Stefan Fassbinder**
Lord Mayor of the University
and Hanseatic City of Greifswald

**Mario Kokowsky**
DEN GmbH

**Prof. Dr. Jürgen Meichsner**
University of Greifswald

**Prof. Dr. Rolf Winkler**
Previously INP

**Dr. Arthur König**
Previous Lord Mayor of the University
and Hanseatic City of Greifswald

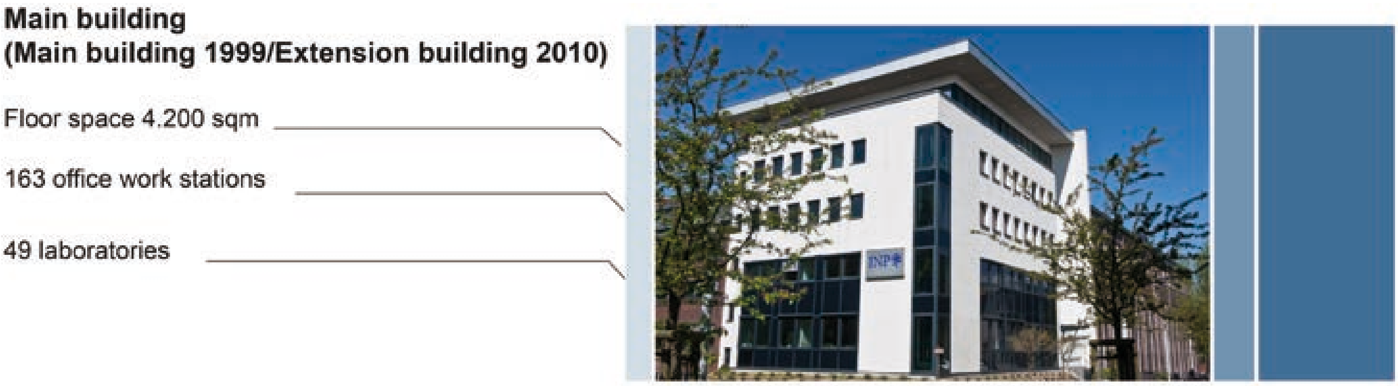
## Facts and Figures

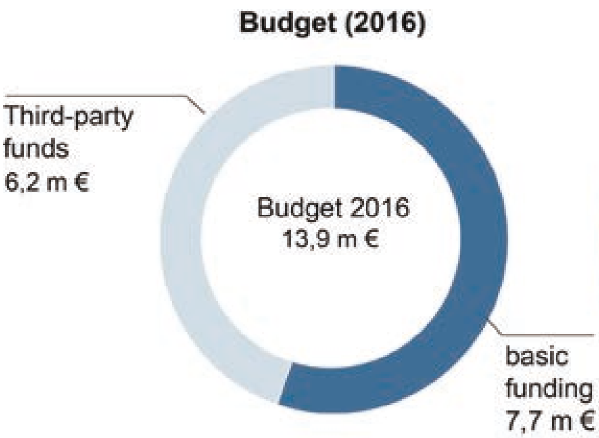
### Budget

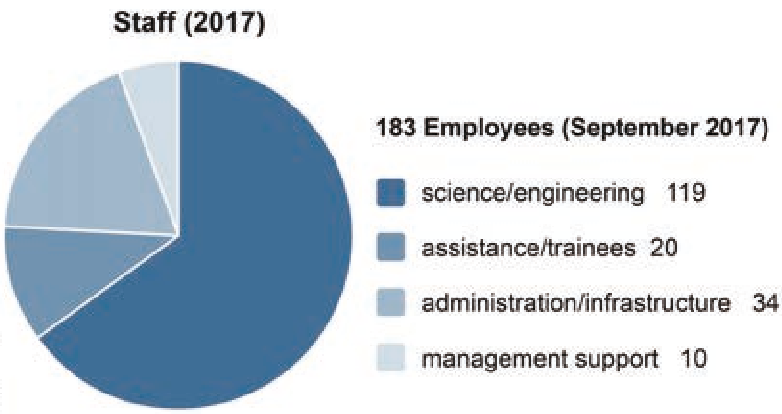
INP had a total budget of about 13.9 million euro in the financial year of 2016 and 17.2 million euro in the financial year of 2017. The staff expenditure amounted to a share of 8.9 million euro (2016) and 9.5 million euro (2017), the material expenditure was 2.9 million euro (2016) and 3.7 million euro (2017). Overall, 2.4 million euro were invested in the equipment of the INP in 2016 and 4.2 million euro in 2017.

### Staff

A total of 183 employees were employed at the INP Greifswald in 2017, of which 119 persons were employed in the scientific and technical areas and 64 in the support and operational areas. The quota of female employees was 39.1 percent.



## Memberships of the INP Greifswald

- RWI - Regionale Wirtschaftsinitiative Ost Mecklenburg-Vorpommern e.V.
- Deutscher Bibliotheksverband e.V.
- idw - Informationsdienst Wissenschaft
- German Water Partnership e. V.
- HYPOS Hydrogen Power Storage & Solutions East Germany e.V.
- Nationales Zentrum für Plasmamedizin e.V.
- Europäische Forschungsgesellschaft Dünne Schichten e.V.
- enviMV e.V. - Umwelttechnologiennetzwerk aus Mecklenburg-Vorpommern
- Deutsche Lichttechnische Gesellschaft e.V.
- Deutsche Physikalische Gesellschaft e.V.
- Forschungsvereinigung Schweißen und verwandte Verfahren e. V. des DVS
- DECHEMA - Gesellschaft für Chemische Technik und Biotechnologie e.V.
- IUTA - Institut für Energie- und Umwelttechnik e. V.
- Carbon Concrete Composite e.V.
- BdP - Bundesverband deutscher Pressesprecher e.V.
- INPLAS - Kompetenznetz Industrielle Plasma-Oberflächentechnik e.V.
- BVMW - Bundesverband mittelständische Wirtschaft, Unternehmerverband Deutschlands e.V.
- WTI - Wasserstofftechnologie-Initiative e.V.
- Hydrogen Europe Research association (former N.ERGHY)
- Greifswald University Club e.V.
- GFaI - Gesellschaft zur Förderung angewandter Informatik e.V.
- Initiative Chronische Wunden e.V.
- Forum MedTech Pharma e.V.
- Deutsche Gesellschaft für Plasmatechnologie e.V.

# COOPERATIONS

- AJ Drexel Plasma Institute
  Philadelphia, USA
- Alexandru Ioan Cuza University of Iasi
  Iași, Romania
- Brno University of Technology
  Brno, Czech Republic
- Chongqing University
  Chongqing, China
- Cogit AG Basel
  Basel, Swiss
- Comenius University in Bratislava
  Bratislava, Slovakia
- Costa Rica institute of Technology
  Cartago, Costa Rica
- CSIRO Manufacturing
  Lindfield, Australia
- Drexel University
  Philadelphia, USA
- Dublin City University
  Dublin, Ireland
- Dutch Institute for Fundamental Energy Research (DIFFER)
  Eindhoven, The Netherlands
- Ecole Polytechnique
  Palaiseau, France
- EMPA - swiss federal laboratories for material science and technology
  Dübendorf, Swiss
- ENIM (École nationale d'ingénieurs de Monastir)
  Monastir, Tunesien
- First Affiliated Hospital Zhejiang University
  Zhejiang, China
- Fudan University
  Shanghai, China
- Hokkaido University
  Hokkaido, Japan
- Holon Institute of Technology
  Holon, Israel
- Institute for Solid State Physics and Optics, Wigner Research Centre for Physics
  Budapest, Hungary
- Institute of High Current Electronics
  Tomsk, Russia
- Institute of Nuclear Chemistry and Technology
  Warszawa, Poland
- Institute of Plasma Physics of the Czech Academy of Science
  Prag, Czech Republic
- Instituto de Plasmas e Fusão Nuclear, Instituto Superior Técnico, Universidade de Lisboa
  Lissabon, Portugal
- International Sakharov Environmental University
  Minsk, Belarus
- Jeju National University
  Jeju, Korea
- Kaunas University of Technology
  Kaunas, Lithuania
- KTH Stockholm
  Stockholm, Schweden
- Kwangwoon University
  Seoul, Korea
- Laboratoire Plasma et Conversion d'Énergie
  Toulouse, France
- Lappeenranta University of Technology
  Mikkeli, Finland
- Lithuanian Energy Institute
  Kaunas, Lithuania
- Lomonosov Moscow State University
  Moscow, Russia

- Lublin University of Technology
  Lublin, Poland
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- National Institute for Laser, Plasma and Radiation Physics
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- Old Dominion University Norfolk
  Norfolk, Virginia
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  Seoul, Korea
- Peking University
  Peking, China
- Plasma Advanced Research Center
  Romania
- PlasmaMedic LTD
  Giv'atayim, Israel
- Polytechnische Universität St. Petersburg
  St. Petersburg, Russland
- Queen's University Belfast
  Belfast, Northern Ireland / UK
- Queensland University of Technology
  Brisbane City, Australia
- Riga Technical University
  Riga, Latvia
- Shandong University
  China
- Southern Methodist University
  Dallas, Texas
- St. Petersburg State University
  St. Petersburg, Russia
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  Gdansk, Poland
- Technical university of Catalonia
  Barcelona, Spain
- Technical University of Denmark
  Roskilde, Denmark
- Technical University of Eindhoven
  Eindhoven, The Netherlands
- Tsinghua University
  Peking, China
- Ufa State Aviation Technical University
  Russia
- Unité d'Études des Milieux Ionisés et Réactifs
  Monastir, Tunisia
- Universidade Estadual Paulista (UNESP)
  Guaratinguetá, Sao Paulo, Brazil
- Università degli Studi di Bari Aldo Moro
  Bari, Italy

- Université d´Orléans
  Orléans, France
- Universite de Pau
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- Université PARIS-SUD
  Orsay, France
- University of California
  Berkeley, USA
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  Michigan, USA
- University of Antwerp
  Antwerp, Belgien
- University of Belgrade
  Belgrade, Serbia
- University of Buenos Aires
  Buenos Aires, Argentina
- University of Cambridge
  Cambridge, UK
- University of Madeira
  Funchal, Portugal
- University of Minnesota,
  Minneapolis, USA
- University of Otago
  Dunedin, Neuseeland
- University of Oxford
  Oxford, UK
- University of Paris-North, LIMHP
  Villetaneuse, France
- University of Pavia
  Pavia, Italy
- University of Purdue
  Lafayette, USA
- University of Tartu
  Tartu, Estonia
- University Paris Sud
  Paris, France
- Uppsala University
  Uppsala, Sweden
- Vilnius Gediminas Technical University
  Vilnius, Lithuania
- Weizmann Institute
  Rehovot, Israel
- West Pomeranian University of Technology
  Szczecin, Poland
- Xi'an Jiaotong University
  Xian, China
- Zhejiang University of Technology
  China

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5. Becker, M.M.; Ponduri, S.; Engeln, R.; van de Sanden, M. C. M.; Sigeneger, F.; Loffhagen, D.: **Influence of the CO2 dielectric barrier discharge conditions on the CO production** Proc. 23rd ESCAMPIG CDROM 2016 P03-06-04

6. Brandenburg, R.; Schiorlin, M.; Klink, R.; Sarani A.: **CO2-conversion in dielectric barrier discharges: Influence of nitrogen admixture on chemistry and discharge physics** Proc. 15th HAKONE 2016

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8. Gericke, A.; Gött, G.; Henkel, K.-M.; Uhrlandt, D.: **Verbesserung des Prozessverständnisses beim Unterpulverschweißen durch optische Analyse des Kavernenraums** Proc. DVS Congress 2016

9. Gerling, T.; Brandenburg, R.; Meyer, C.; Wilke, C.; Weltmann, K.-D.: **Power measurement for an Atmospheric Pressure Plasma Jet at Different Frequencies - Distribution in the Core Plasma and the Effluent** Proc. 15th HAKONE 2016

10. Gortschakow, S.; Baeva, M.; Kozakov, R.; Uhrlandt, D.; Kalanov, D.; Golubovskii, Yu.: **Chemical non-equilibrium in a free-burning argon arc** Proc. 21th Int. Conf Gas Discharges and their Applications CDROM 2016 85

11. Gortschakow, S.; Bogaczyk, M.; Kozakov, R., Arumugam, S.: **Use of optical emission for diagnostics of partial discharges in XLPE cables** Proc. 21th Int. Conf Gas Discharges and their Applications CDROM 2016 597

12. Grofulovic, M.; Loffhagen, D.; Pinhao, N. R.; Alves, L. L.; Guerra, V.; Korolov, I.; Vass, M; Donko, Z.: **Intercomparison of calculation techniques of the electron Boltzmann equation for the analysis of swarm parameters in CO2** Proc. 23rd ESCAMPIG CDROM 2016 64

13. Harhausen, J.; Foest, R.; Loffhagen, D.; Stenzel, O.; Wilbrandt, S.; Franke C.; Kaiser, N.: **Plasma diagnostics for efficient optimization of optical coatings** Proc. 11th Int. Conf. on Coatings on Glass and Plastics CDROM 2016 241-245

14. Höft, H.; Becker, M.; Kettlitz, M.: **The influence of the HV slope steepness on the breakdown and develoment of pilsed** Proc. 21th Int. Conf Gas Discharges and their Applications Vol.1 2016 353-356

15. Höft, H.; Becker, M.; Kettlitz, M.: **On the influence of gas flow rate on the behaviour of dielectric barrier discharges** Proc. 23rd ESCAMPIG P02-05-08 2016 211-212

16. Janda, M.; Hoder, T.; Sarani, A.; Brandenburg, R.; Machala, Z.: **Cross-correlation spectroscopy study of the breakdown mechanism in atmospheric pressure air transient spark discharge** Proc. 15th HAKONE 2016

17. Janda, M.; Hoder, T.; Sarani, A.; Brandenburg, R.; Machala, Z.: **Cross-correlation spectroscopy study of the Transient Spark discharge** Proc. 23rd ESCAMPIG 2016

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20. Kozakov, R.; Bogaczyk, M.; Gortschakow, S.: **Combined electrical and optical partial discharge diagnostics** Proc. 14th High-Tech Plasma Processes Conference Band 1 2016 63

21. Lang, N.; Macherius, U.; Wiese, M.; Zimmermann, H.; Röpcke, J.; van Helden, J. H.: **Applying quantum cascade laser based optical feedback cavity-enhanced absorption spectroscopy in sensing atmospheric methane** Proc. OSA-Meeting LM3G.5 2016

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24. Methling, R.; Popov, S.; Batrakov, A.; Uhrlandt, D.: **Spectrally and Spatially Resolved Imaging of an Anode Flare in the Initial Stage of a Vacuum Arc Discharge** Proc. 27th ISDEIV Vol1 2016 259-262

25. Pettersson, J.; Becerra, M.; Franke, St.; Gortschakow, S.; Khakpour, A.; Bianchetti, R.: **Space-Resolved Spectroscopic And Photographic Studies Of The Vapor Layer Produced By Arc-Induced Ablation Of Polymers** Proc. 21th Int. Conf Gas Discharges and their Applications Vol.1 2016 149-152

26. Popov, S.; Methling, R.; Kanonykhin,A.: **The Spectroscopy of Cathode Spot of Pulsed Vacuum Arc Discharge in a Wide Range of Current** Proc. 27th ISDEIV Vol1 2016 371-374

27. Röpcke, J.; Hamann, S.; Hanneman, M.; Lang, N.; Nave, A.; van Helden, J. H.: **On Recent Progress in Plasma Diagnostics and Trace Gas Detection Using Infrared Laser Techniques** Proc. OSA-Meeting Etu2A.2 2016

28. Sigeneger, F.; Schäfer, J.; Foest, R.; Loffhagen, D.: **Modelling of an RF plasma jet at atmospheric pressure using complementary approaches** Proc. 23rd ESCAMPIG CDROM 2016 P02-11-03

29. van Helden, J. H.; Gianella, M.; Reuter, S.; Lang, N., Ritchie, G. A. D.; Röpcke, J.: **The detection of the highly reactive HO2 radical and of CH4 in atmopsheric pressure plasma jets** Proc. OSA-Meeting LTh2I.2 2016

30. van Helden, J. H.; Lang, N.; Nave, A.; Macherius, U.; Zimmermann, H.; Wiese, M.; Röpcke, J.: **Sensitive Spectroscopy of Plasmas in the Mid-Infrared Spectral Range, DOI: 10.1364/MICS.2016.MT1C.2** Proc. OSA-Meeting 2016

31. Winter, J.; Schmidt-Bleker, A.; Santos Sousa, J.; Bösel, A.; Hänel, M.; Reuter, S.; Sadeghi, N.; Peuch, V.; Weltmann, K.-D.: **Characterization of microplasma jets by infrared absorption spectroscopy** Proc. 23rd ESCAMPIG 2016

## ARTICLES IN PEER-REVIEWED PROCEEDINGS 2017

1. Baeva, M.; Uhrlandt, D.; Murphy, A. B.: **Collisional-radiative model of iron vapour released in thermal arc plasma from molten electrodes** Proc. 33rd ICPIG CDROM 2017 149

2. Becker, M.; Philipp, J.; Czerny, A.; Klages, C.-P.; Loffhagen, D.: **Ignition behaviour of atmospheric-pressure dielectric barrier discharges in argon with admixtures of hexamethyldisiloxane and tetramethylsilane** Proc. 33rd ICPIG CDROM 2017 144

3. Brandenburg, R., Sarani, A.: **Development of microdischarges in carbon dioxide with and without admixture of nitrogen** Proc. 21th Symp. Appl. Plasma Processes 2017

4. Gerling, T.; Becker, M. M.; Wilke, C.; Weltmann, K.-D.: **Absolute ion densities in an atmospheric pressure plasma transient spark discharge for different oxygen admixtures** Proc. 21st SAPP Conf. CDROM 2017 HT-16

5. Golubovskii, Y.; Kalanov, D.; Maiorov, V.; Baeva, M.; Uhrlandt, D.; Gortschakow, S.: **Radiation trapping in non-equilibrium plasmas: matrix methods and its application to arcs and glow discharges** Proc. 33rd ICPIG CDROM 2017 244

6. Haase, M.; Zimmermann, H.; Lang, N.; Ecke, R.; Röpcke, J.; van Helden, J.-P.; Schulz, S.: **Correlation between the ULK sidewall damage an the Doppler broadening of a CF2 absorption line** Proc. 10th PESM 2017 Session 4

7. Klages, C.-P.; Czerny, A. K.; Philipp, J.; Becker, M. M.; Loffhagen, D.: **Analytical model of monomer reactions with excited argon species in DBD-based plasma polymerization at atmospheric pressure** Proc. IWM 9 CDROM 2017 16

8. Korolov, I.; Vass, M.; Loffhagen, D.; Pinhao, N.; Donko, Z.: **Measurements and kinetic computations of electron transport parameters in CO2 in an extended E/N range** Proc. 33rd ICPIG CDROM 2017 234

9. Panousis, E.; Stoller, P.; Carstensen, J.; Teppati,V.; Methling,R.; Franke, St.; Gortschakow, S.: **Active and passive optical diagnostics in a model HV circuit breaker** Proc. 33rd ICPIG 2017

10. Schmidt, M.; Altrock, B.; Gerling, T.; Gerber, I. C.; Hahn, V.; Weltmann, K.-D.; von Woedtke, Th.: **AC-driven pin-to-liquid discharge: characterization and application** Proc. 23rd ISPC WEB, ID 190 2017

11. Schmidt,M.; Kettlitz, M.; Timmermann. E.; Brandenburg, R.: **Odour treatment in humid atmosphere with non-thermal plasma and electric wind** Proc. 23rd ISPC WEB, ID 103 2017

12. Vass, M.; Korolov, I.; Loffhagen, D.; Pinhao, N.; Donko, Z.: **Measurements and kinetic computations of electron transport parameters in CO2** Proc. 21th Symp. Appl. Plasma Processes 2017 231-235

13. Winter, J.; Glitsch, S.; Lühder, H.; Schmidt-Bleker, A.; Bansemer, R.; Wende, K.; Szymiczek, D.; Lösche, Ch.; Scharf, Ch.; Ehlbeck, J.; Weltmann, K.-D.: **On the application of atmospheric pressure plasma jets in endoscopy** Proc. 23rd ISPC WEB, ID 130 2017

## INVITED TALKS 2016

1. Baeva,M.: **Thermische und chemische Nichtgleichgewichtseffekte in freibrennenden Bogenplasmen** DPG Frühjahrstagung Plasmaphysik, Hannover/Deutschland 2016

2. Bekeschus, S.; Rouven, K.R.; Heidecke, C.-D.; von Woedtke, T.; Partecke, L.I.: **Cold physical plasma-treated medium demonstrates antitumor activity against pancreatic cancer cells in vitro an in vivo** 6th Int. Conf. on Plasma Medicine, Bratislava/Slovakia 2016

3. Brandenburg, R.; Schiorlin, M.; Klink, R.; Sarani A.: **Barrier discharges in CO2 containing gases at atmospheric pressure** 28th Summer School and Int. Symp. on the Physics of Ionized Gases (SPIG 2016), Belgrade/Serbia 2016

4. Finke, B.; Rebl, H.; Nebe, B.; Zietz, C.; Gabler, C.; Bader, R.; Walschus, U.; Schlosser, M.; Weltmann, K.-D.; Polak, M.: **Cell-adhesive finishing of implant surfaces by plasma polymerized allylamine - PPAAm** Thermec, Graz/Österreich 2016

5. Foest, R.: **Plasma diagnostics for efficient optimization of optical coatings** 11th Int. Conf. on Coatings on Glass and Plastics, Braunschweig/Germany 2016

6. Grünwald, J.: **Copper based anti-microbial films deposited by atmospheric pressure plasma sources** EMN Meeting on Biomaterials, Phuket/Thailand 2016

7. Khakpour, A.: **High-current anode phenomena in vacuum arc** 10th Int. Symp. on Non-Thermal/Thermal Plasma Pollution Control Technology & Sustainable Energy, Florianopolis/Brazil 2016

8. Kolb, J. F.; Ehlbeck, J.; Schnabel, U.; Andrasch, M.; von Woedtke. Th.; Brandenburg, R.; Weltmann, K.-D.: **Direct and Indirect Treatment of Perishable Food with Atmospheric Pressure Plasmas** 6th Int. Conf. on Microelectronics and Plasma Technology, Gyengjou/Korea 2016

9. Kolb, J.-F.; Zocher, K.; Steuer, A.; Winter, J.; Ehlbeck, J.; von Woedtke, Th.; Weltmann, K.-D.: **Non-thermal Plasma and Pulsed Electric Fields for the Extraction of Valuable Substances from Plant Cells** 1st Int. Workshop on Plasma Agriculture, Philadelphia/USA 2016

10. Kruth, A.; Brüser, V; Weltmann, K.-D.: **Plasma-enhanced Deposition of New Electrode Materials for Renewable Energy Applications** iPlasmaNano-VII, Attica/Greece 2016

11. Kruth, A.; Müller, A.; Peglow, S.; May, F.; Quade A.; Brüser, V.; Scheu, C.; Weltmann, K.-D.: **Magnetron Sputtering Deposition of Photocatalyst Nanostructures for Solar Applications** Eur. Advanced Materials Congress, Stockholm/Sweden 2016

12. Kruth, A.; Peglow, S.; May, F.; Quade A.; Brüser, C.; Weltmann, K.-D.: **Magnetron Sputtering for Deposition of Photocatalyst Nanostructures on Transparent Conductive Oxides for Solar Applications** 29th Electrochemistry Society Meeting, San Diego/USA 2016

13. Lukes, P.; Clupek, M.; Babicky, V.; Pongrac, B.; Simek, M.; Kolb, J.-F.: **On the mechanism of OH radical formation by nanosecond pulsed corona discharge in water** 43rd IEEE Int. Conf. on Plasma Science (ICOPS), Banff/Canada 2016

14. Masur, K; Hasse, S; Wende, K; von Woedtke, Th; Metelmann, HR, Weltmann, KD **Cold Plasma Mediated Influence on Cellular Redox Balance to Support Wound Healing** 6th Int. Conf. on Plasma Medicine, Bratislava/Slovakia 2016

15. Masur, K; Hasse, S; Wende, K; von Woedtke, Th; Metelmann, HR, Weltmann, KD **Plasma Medicine: From Bench to Bedside** 25th IVC / 6th ICPB, Busan/South Korea, 2016

16. Miron, C.; Kruth, A.; Zhuang, J.; Quade, A.; Sava, I.; Hulubei, C.; Holub, M.; Balcerak, M.; Bonislawski, M.; Weltmann, K.-D; Kolb, J. F.: **Structural Modifications of Materials by Plasma Discharges in Liquids** Emerging Polymer Technologies Summit, Melbourne/Australia 2016

17. Nebe, B.; Moerke, C.; Staehlke, S.; Finke, B.; Schnabelrauch, M.; Anselme, K.; Helm, C.; Rebl, H.: **Complex cell physiology on topographically and chemically designed material surfaces** Thermec, Graz/Österreich 2016

18. Pei, X.; Kolb, J.-F.; Lu, X.: **On the Mechanisms of Cold Atmospheric Pressure Direct Current Driven Air/N2 Plasma Jets** 43rd IEEE Int. Conf. on Plasma Science (ICOPS), Banff/Canada 2016

19. Röpcke, J.; Hamann, S.; Hannemann, M.; Lang, N.; Nave, A. S. C.; van Helden, J. H.: **On Recent Progress in Plasma Diagnostics and Trace Gas Detection Using Infrared Laser Techniques** XXXVII Congresso Brasileiro de Aplicações de Vácuo na Indústria e na Ciência (CBrAVIC), Bauru/Brazil 2016

20. Röpcke, J.; Hamann, S.; Hannemann, M.; Lang, N.; Nave, A.; van Helden, J. H.: **On recent progress in studying chemical phenomena and surface interactions in plasmas using infrared absorption techniques** 27th Symp. Plasma Physics and Technol. (SPPT), Praha/Czech Republic 2016

21. Schmidt, A. **Cell migration and adhesion of two human cancer cell lines are decreased by cold plasma treatment** 3rd Int. Workshop on Plasma for Cancer Treatment, Washington D.C./USA 2016

22. Schnabel, U.; Stachowiak, J.; Schlüter, O.; Andrasch, M.; Ehlbeck, J.: **Scale up to pilot plant dimensions of plasma processed water generation for fresh-cut lettuce treatment** Workshop on Application of Advanced Plasma Technologies in CE Agriculture, Ljubljana/Slovenia 2016

23. Tschiersch, R.; Bogaczyk, M.; Nemschokmichal, S.; Meichsner, J.: **Spatio-temporal characterisation of multiple diffuse and single filamentary breakdowns in a plane-parallel barrier discharge configuration** DPG Frühjahrstagung Plasmaphysik, Hannover/Deutschland 2016

24. Uhrlandt, D., Baeva, M.: **Electric confinement and power budget of a free burning arc** 14th High-Tech Plasma Processes Conference, Munich/Germany 2016

25. van Helden, J. H.; Lang, N.; Nave, A; Röpcke, J: **Mid-infrared cavity enhanced absorption spectroscopy of gas and surface species** DPG Frühjahrstagung Plasmaphysik, Hannover/Deutschland 2016

26. van Helden, J.H.; Nave, A; Reuter, S; Röpcke, J; M. Gianella; G.A.D. Ritchie **Cavity-enhanced absorption spectroscopy to characterize atmospheric pressure plasma jets** 69th GEC, Bochum/Germany 2016

27. von Woedtke, Th. **Progress and Challenges in Plasma Medicine** 13th Int. Bioelectrics Symp., Rostock/Germany 2016

28. von Woedtke, Th. **The redox potential in liquids as possible parameter to estimate and compare biological plasma effects** 6th Int. Conf. on Plasma Medicine, Bratislava/Slovakia 2016

29. Weltmann, K.-D.: **Cold Atmospheric Pressure Plasma Applications for Medicine, Hygiene and Food** 21st Int. Conf. on Gas Discharges and their Applications, Nagoya/Japan 2016

30. Weltmann, K.-D.: **Decontamination and Preservation of Perishable Food with Atmospheric Pressure Plasmas** 1st Int. Workshop on Plasma Agriculture, Philadelphia/USA 2016

31. Weltmann, K-D., von Woedtke, Th. **Plasma Medicine innovative physics for medical application** 43rd EPS Conference on Plasma Physics, Leuven/Belgium 2016

32. Winter, J.; Schmidt-Bleker, A.; Santos Sousa, J.; Bösel, A.; Hänel, M.; Reuter, S.; Sadeghi, N.; Peuch, V.; Weltmann, K.-D.: **Characterization of microplasma jets by infrared absorption spectroscopy** 23rd ESCAMPIG, Bratislava/Slovakia 2016

## INVITED TALKS 2017

1. Baeva, M.; Uhrlandt, D.: **Advanced nonequilibrium modelling of DC tungsten-inert gas arcs** 22th Symp. on Physics of Switching Arc, Brno/Czech Republic 2017

2. Bekeschus, S.: **Plasma medicine and research at ZIK plasmatis, Journal Club Institute of Immunology, Greifswald, 2017** 10th Int. FRUTIC Symp., Berlin/Germany 2017

3. Brandenburg, R.: **Dielectric Barrier Discharges: Known since 160 years, but still a lot of potential for innovations** XXXVIII CBrAVIC, São José dos Campos/Brasilien

4. Brüser, V.: **Environmental applications of plasma technology** 17th International Scientific Conference "Sakharov Readings", Minsk/Weißrussland 2017

5. Gerling, T.; Becker, M.M.; Wilke, C.; Weltmann, K.-D.: **Applying fast electrical diagnostics to access absolute ion densities in an atmospheric pressure plasma** 21st SAPP, Strbske Pleso/Slovakia 2017

6. Hamann, S; Burlacov I.; Spies, H.-J.; Biermann, H.; Röpcke, J.: **New Developments in Plasma Nitriding with an Active Screen** 18. Fachtagung Plasmatechnologie, Göttingen/Deutschland 2017

7. Harhausen, J.; Franke, C.; Foest, R.; Stenzel, O.; Wauer, J.; Wilbrandt; S.: **Plasmagestützte Bedampfung zur Herstellung von Präzisions¬optiken: Prozessanalytik und Regelungs¬verfahren** 18. Fachtagung Plasmatechnologie, Göttingen/Deutschland 2017

8. Harhausen, J.; Franke, C.; Foest, R; Stenzel, O.; Wauer, J.; Wilbrandt, S.: **Diagnostics and Control Schemes for Industrial PIAD Processes** DPG Frühjahrstagung Plasmaphysik, Bremen/Deutschland 2017

9. Hasse, S. **Plasma Treatment for Skin cancer and medical applications** 2nd Industry-Academy Plasma Medicine Workshop, Seoul, Korea, 2017

10. Hasse, S.; Wende, K. **Present applications of cold atmospheric plasma (CAP) in medicine main focus: wound healing International Forum on Functional Materials** (IFFM2017)/ 7th International Symposium on Plasma Biosciences (ISPB2017-7), Jeju Korea, 2017

11. Kolb, J.F.; Banaschik, R.; Kredl, J.; Schulz, T.; Miron, C.; Lukes, P.; Bednarski, P.J.; Weltmann, K.-D.: **Environmental Applications of Plasmas in Liquids** 5th International Workshop and the 4th International Mini Workshop on Solution Plasma and Molecular Technologies, Greifswald/Deutschland 2017

12. Kolb, J.F.; Miron, C.; Rataj, R.; Kredl, J.; Schulz, T.; Lukes, P.: **Pulsed Discharges in Liquids: Generation and Applications** ICOPS, Atlantic City, New Jersey USA 2017

13. Lang, N.; Macherius, U.; Zimmermann, H.; Wiese, M.; Glitsch, S.; Hamann, S.; Röpcke, J.; van Helden, J. H.: **Diagnostic studies of technological plasmas using quantum cascade lasers** 18th LAPD, Prague/Czech Republic 2017

14. Loffhagen, D.: **Modellierung von dielektrisch behinderten Entladungen zur Dünnschichtabscheidung** 18. Fachtagung Plasmatechnologie, Göttingen/Deutschland 2017

15. Masur, K. **Plasma Medicine: From Bench to Bedside the Need for Standardization** 1st Joint Workshop of INP-PBRC Applied Plasma Medicine Center (APMC), Seoul, Korea, 2017

16. Masur, K. **Kalte Physikalische Plasmen für die Heilung chronischer Wunden** 2. WundD.A.CH Dreiländerkongress, St. Gallen/Schweiz 2017

17. Masur, K.; Hasse, S.; von Werder, Y.; Metelmann, H.-R.; Weltmann, K.-D.; von Woedtke, Th. **Towards clinical application of cold atmospheric pressure plasma International Forum on Functional Materials** (IFFM2017)/ 7th International Symposium on Plasma Biosciences (ISPB2017-7), Jeju Korea, 2017

18. Masur, K.; von Woedtke, Th.; Weltmann, K.-D. **Plasma Medicine: Harmonization of Cold Plasma Application Annual** GRDC Meeting, Seoul/ Korea, 2017

19. Miron, C.; Kruth, A.; Quade, A.; Weltmann, K.D.; Kolb, J.F.: **Optical and mechanical properties of polymers treated by plasma in liquids** 5th International Workshop and the 4th International Mini Workshop on Solution Plasma and Molecular Technologies, Greifswald/Deutschland 2017

20. Röpcke, J.; Hamann, S.; Hannemann, M.; Lang, N.; Nave, A.; van Helden, J.-P.: **On Recent Progress using Infrared Absorption Techniques for Diagnostic and Control of Process Plasmas** 11th Asian-Eur. Int. Conf. Plasma Surf. Eng., Jung-mun/Korea 2017

21. Schäfer, J.: **Searching for Order in Atmospheric Pressure Plasma Jets** 44th EPS Belfast, UK 2017

22. Schmidt, A. **One year follow up risk assessment in plasma-treated mice International Forum on Functional Materials** (IFFM2017)/ 7th International Symposium on Plasma Biosciences (ISPB2017-7), Jeju Korea, 2017

23. Testrich, H.: **Plasma sprayed coating for bone replacement with anti-microbial properties** FiMPART Bordeaux, Frankreich 2017

24. van Helden, J. H.; Nave, A; Reuter, S.; Röpcke, J.; Lawry Aguila, A.; Gianella M.; Ritchie, G.A.D.: **Cavity-enhanced absorption spectroscopy of reactive species in atmospheric pressure plasma jets** 18. Fachtagung Plasmatechnologie, Göttingen/Deutschland 2017

25. van Helden, J. H.; Reuter, S.; Lawry Aguila, A.; Gianella M.; Ritchie, G.A.D.: **Characterizing atmospheric pressure plasma jets using cavity-enhanced absorption spectroscopy** DPG Frühjahrstagung Plasmaphysik, Bremen/ Deutschland 2017

26. von Woedtke, Th. **Clinical Plasma Medicine: Current State and Perspectives** 1st Joint Workshop of INP-PBRC Applied Plasma Medicine Center (APMC), Seoul, Korea, 2017

27. von Woedtke, Th. **Grundlagen der Plasmamedizin und zukünftige Entwicklungen** 2. WundD.A.CH Dreiländerkongress, St. Gallen/Schweiz 2017

28. von Woedtke, Th.; Metelmann, H.-R.; Weltmann, K.-D. **Present applications of cold atmospheric plasma (CAP) in medicine main focus: wound healing** International Forum on Functional Materials (IFFM2017)/ 7th International Symposium on Plasma Biosciences (ISPB2017-7), Jeju Korea, 2017

29. Weltmann, K.-D.; Brandenburg, R.; Gerling, T.; von Woedtke, Th.: **Development of plasma sources for medical applications** Int. Conf. on Plasma Medical Science Innovation (ICPMSI), Nagoya/Japan 2017

30. Weltmann, K.-D.; v. Woedtke, Th.; Kolb, J.F.; Gerling, T.: **Cold Atmospheric Plasma (CAP) in Life Sciences** 70th GEC, Pittsburgh/USA 2017

31. Weltmann, K.-D.; von Woedtke, Th.: **Plasma Medicine Status of Basic Research and Transfer into the Hospital** 9th ISPlasma, Aichi/Japan 2017

32. Wende, K.: **Plasmas in Biology Beyond the Long Lived Species** International Conference on Plasmas with Liquids (ICPL 2017), Prague/Czech Republic 2017

33. Wende, K.; Bruno, G.; Lackmann, J.-W.; Volzke, J.; Verlackt, C.; Bogaerts, A.; Bekeschus, S.; Stapelmann, K.; Weltmann, K.-D.: **Chemical Fingerprinting to Design Medical Plasmas** 10th EU-Japan Joint Symposium on Plasma Processing (JSPP2017), Okinawa/ Japan, 2017

34. Wende, K.; Jablonowski, H.; Lackmann, L.; Bruno, G.; Lalk, M.; von Woedtke, T.; Bruggeman, P.; Weltmann, K.-D.: **Plasma medicine beyond the long lived species** 15th Technological Plasma Workshop, Conventry/ UK, 2017

35. Wende, K.; Masur, K.; Bekeschus, S.; Jablonowski, H.; Schmidt, A.; von Woedtke, T.: **On the biology of plasmas** 21st Symposium on Applications of Plasma Processes, trbské Pleso/ Slovakia, 2017

## TALKS 2016

1. A. Steuer, K. Wende, P. Babica, J.F. Kolb **Nanosecond Pulsed Electric Fields Decrease the Elasticity of WB F344 Cells Exposed in Monolayers** 13th Int. Bioelectrics Symp., Rostock/Germany 2016

2. Andrasch, M.: **Entladungsdynamik einer Mikrowellenplasma-quelle und ihr Einsatz bei Atmosphärendruck zur Dekontamination von Lebensmitteln im technologischen Maßstab** DPG Frühjahrstagung Plasmaphysik, Hannover/Deutschland 2016

3. Andrasch, M.; Schnabel, U.; Stachowiak, J.; Niquet, R.; Ehlbeck, J.: **Microwave induced plasma for food sanitizing in a technological scale** 50th Annual Microwave Power Symp. (IMPI 50), Orlando/USA 2016

4. Andrasch, M.; Stachowiak, J.; Schlüter, O.; Schnabel, U.; Ehlbeck, J.: **Scale-up to pilot plant dimensions of plasma processed water generation for fresh-cut lettuce treatment** 18th World Congress of Food Science and Technology (IUFoST2016), Dublin/Ireland 2016

5. Andreev, V.; Brandenburg, R.; Sarani, A.; Kettlitz, M.: **Investigation of single filaments in a dielectric barrier discharge with rotating electrode** 15th HAKONE, Brno/Czech Republic 2016

6. Baeva, M.; Siewert, E.; Uhrlandt, D.: **Electric field and voltage of TIG arcs from non-equilibrium modelling and experiment** 21st Int. Conf. on Gas Discharges and their Applications, Nagoya/Japan 2016

7. Baeva, M.; Uhrlandt, D.; Siewert, E.: **Electrical characteristics of TIG arcs in argon from non-equilibrium modelling and experiment** 69th GEC, Bochum/Germany 2016

8. Becker, M.; Kahlert, H.; Sun, A.; Bonitz, M.; Loffhagen, D.: **Advanced fluid modelling of low pressure ccrf discharges** Intern. SFB-TR24 Konferenz: Quo vadis - Complex Plasmas, Hamburg/Germany 2016

9. Becker, M.M.; Ponduri, S.; Engeln, R.; Loffhagen, D.: **Modellierung der CO2-Dissoziation in dielektrisch behinderten Entladungen** DPG Frühjahrstagung Plasmaphysik, Hannover/Deutschland 2016

10. Bekeschus, S.: **Cold physical plasma derived oxidants - challenges and opportunities for medical therapy** 5th Young Professionals Workshop on Plasma Medicine, Rostock/Germany 2016

11. Bekeschus, S.: **A redox-based, multi-focus cancer research approach in plasma medicine** 2nd Future in Plasma Science Workshop, Greifswald/Germany 2016

12. Bekeschus, S.; Liedtke, K. R.; Partecke, L. I.: **Plasma-treated medium reduced tumor burden and enhanced survival in a syngeneic murine tumor model** 3rd Int. Workshop on Plasma for Cancer Treatment, Washington D.C./USA 2016

13. Brüser, V.; Popvitz-Biro, R.; Peglow, S.; Zak, A.: **Plasma Treatment of MWINT-WS2 for Synthesis of Single Wall Nanotubes of WS2** 3rd GermanCzech Workshop, Lübeck/Germany 2016

14. Franke, St.: **Broadband absorption tecnique to a free-burning arc in ambient air** 21st Int. Conf. on Gas Discharges and their Applications, Nagoya/Japan 2016

15. Fricke, K.: **Creating Biointerfaces: From Metallic and Polymer-like to Calcium phosphate-based mineral coatings to control biological responses** 25. Workshop des AK-ADP, Erfurt/Deutschland 2016

16. Fröhlich, M.; Gauter, S.; Garkas, W.; Weltmann, K.-D.; Kersten, H.; Polak, M.: **Influence of high voltage pulsed bias on surfaces treated by HiPIMS** 7th HiPIMS Conf., Sheffield/UK 2016

17. Fröhlich, M.; Gauter, S.; Garkas, W.; Weltmann, K.-D.; Kersten, H.; Polak, M.: **Concept of calorimetric measurements determining the energy flux onto high voltage pulsed substrate during HiPIMS deposition** 15th PSE, Garmisch-Partenkirchen/Germany 2016

18. Fröhlich, M.; Ihrke, R.; Quade, A.; Weltmann, K.-D.; Polak, M.: **Hochglanzpolieren mit Plasma Was der vierte Aggregatzustand noch alles möglich macht** 23. Erfahrungsaustausch Oberflächentechnologie mit Plasma- und Ionenstrahlprozessen, Mühlleithen/Deutschland 2016

19. Gerling, T.; Brandenburg, R.; Meyer, C.; Wilke, C.; Weltmann, K.-D.: **Power measurement for an Atmospheric Pressure Plasma Jet at Different Frequencies - Distribution in the Core Plasma and the Effluent** 15th HAKONE, Brno/Czech Republic 2016

20. Gerling, T; Becker, M. M.; Wilke, C; Weltmann, K.-D.: **Measurement of molecular argon ion density at atmospheric pressure** DPG Frühjahrstagung Plasmaphysik, Hannover/Deutschland 2016

21. Gortschakow, S.: **Chemical non-equilibrium in a free-burning argon arc** 21st Int. Conf. on Gas Discharges and their Applications, Nagoya/Japan 2016

22. Gortschakow, S.: **Video spectroscopy of vacuum arc during transition between different high-current anode modes** 27th ISDEIV, Suzhou/China 2016

23. Hamann, S.; Börner, K.; Burlacov, I.; Spies, H.-J.; Röpcke, J.: **Spectroscopic investigations of active screen plasma nitriding processes: a comparative study of two reactor types** 7th IPS, Inuyama/Japan 2016

24. Harhausen, J.; Foest, R.; Loffhagen, D.; Wauer, J.; Stenzel, O.; Wilbrandt, S.; Franke, C.: **Advances in characterization and control of plasma ion assisted deposition processes** 15th PSE, Garmisch-Partenkirchen/Germany 2016

25. Hasse, S; Wende, K., Masur, K., Schmidt. A., von Woedtke. Th., Metelmann, HR **Cold argon plasma as an adjuvant therapy option in progressive head and neck cancer - results of a preclinical study** 6th Int. Conf. on Plasma Medicine, Bratislava/Slovakia 2016

26. Höft, H. **Einfluss der Flankensteilheit auf den Durchbruch von dielektrisch behinderten Entladungen** DPG Frühjahrstagung Plasmaphysik, Hannover/Deutschland 2016

27. Höft, H.: **The influence of the HV slope steepness on the breakdown and develoment of pilsed** 21st Int. Conf. on Gas Discharges and their Applications, Nagoya/Japan 2016

28. J.-W. Lackmann, K. Wende, K. Stapelmann **Cysteine as a Model for Comparing the Impact of Plasmas on Biological Samples** 6th Int. Conf. on Plasma Medicine, Bratislava/Slovakia 2016

29. Jablonowski L, Kerlikowski A, Matthes R, Pink C, Schlüter R, Steffen H , Weltmann K, von Woedtke T, Kocher T **Atmospheric Pressure Plasma against Candida albicans Biofilms in Root Canals** 35th Annual Meeting of the IADR Korean Division, Seoul/South Korea 2016

30. Jablonowski L, Kocher T, Dombrowski F, Schindler A, von Woedtke T, Evert M, Evert KW **Atmospheric pressure plasma application in the oral cavity: Short term experiments in mice** 6th Int. Conf. on Plasma Medicine, Bratislava/Slovakia 2016

31. Jablonowski, H; Santos Sousa, J; Schmidt-Bleker, A; Winter, J; Wende, K; v. Woedtke, Th; Weltmann, K-D; Reuter, S **Plasma induced reactive oxygen species in biorelevant liquids: different species have various origins** 6th Int. Conf. on Plasma Medicine, Bratislava/Slovakia 2016

32. Jablonowski, H; Santos Sousa, J; Schmidt-Bleker, A; Winter, J; Wende, K; v. Woedtke, Th; Weltmann, K-D; Reuter, S P**lasma induced reactive oxygen species in biorelevant liquids: different species have various origins** 5th Young Professionals Workshop on Plasma Medicine, Rostock/Germany 2016

33. Janda, M.; Hoder, T.; Sarani, A.; Brandenburg, R.; Machala, Z.: **CROSS-CORRELATION SPECTROSCOPY STUDY OF THE BREAKDOWN MECHANISM IN ATMOSPHERIC PRESSURE AIR TRANSIENT SPARK DISCHARGE** 15th HAKONE, Brno/Czech Republic 2016

34. Janda, M.; Hoder, T.; Sarani, A.; Brandenburg, R.; Machala, Z.: **Cross-correlation spectroscopy study of the Transient Spark discharge** 23rd ESCAMPIG, Bratislava/Slovakia 2016

35. K. Wende, F. Naeser, C. Bäcker, K.-D. Weltmann, U. Lindequist,Th. von Woedtke, B. Haertel **Stimulation of Metabolite Production in Medical Fungi by Atmospheric Pressure Plasmas** 1st Int. Workshop on Plasma Agriculture, Philadelphia/USA 2016

36. K. Wende, F. Naeser, C. Bäcker, K.-D. Weltmann, U. Lindequist,Th. von Woedtke, B. Haertel **Stimulation of medical mushroom metabolism by Atmospheric Pressure Plasma Workshop on Application of Advanced Plasma Technologies in CE Agriculture**, Ljubljana/Slovenia 2016

37. K. Wende, M. Loening, J. Volzke, A. Schmidt, S. Hasse, C. Hackbarth, K. D. Weltmann,S. Bekeschus, P. Bruggeman, Th. von Woedtke **On the chemistry of remote effects of non-thermal plasmas** 6th Int. Conf. on Plasma Medicine, Bratislava/Slovakia 2016

38. Kolb, J.-F.; Miron, C.; Kruth, A.; Balcerak, M.; Bonislawski, M.; Holub, M.: **Development and applications of discharges generated in liquids with short high voltage pulses** 69th GEC, Bochum/Germany 2016

39. Kristian Wende, F. Näser, C. Bäcker, K.-D. Weltmann, U. Lindequist,Th. von Woedtke, B. Haertel **ATMOSPHERIC PRESSURE PLASMAS IN BIOTECHNOLOGY** 13th Int. Bioelectrics Symp., Rostock/Germany 2016

40. Lang, N.; Hamann, S.; Dieguez-Alonso, A.; Röpcke, J.; van Helden, Jean-Pierre H.: **Sensitive detection of atmospheric methane with optical feedback cavity-enhanced absorption spectroscopy in the mid-infrared spectral range** FLAIR, Aix-Les-Bains/France 2016

41. Lang, N.; Hamann, S.;Dieguez-Alonso, A.; Röpcke, J.; van Helden, J. H.: **Analysis of the product gas composition in pyrolysis processes of single wood particles using FTIR spectroscopy** OSA Meeting LEEC, Leipzig/Germany 2016

42. Lang, N.; Macherius, U.; Wiese, M.; Zimmermann, H.; Röpcke, J.; van Helden, J.H.: **Applying quantum cascade laser based optical feedback cavity-enhanced absorption spectroscopy in sensing atmospheric methane** OSA Meeting LACSEA, Heidelberg/Germany 2016

43. Lang, N.; Zimmermann, S.; Zimmermann, H.; Macherius, U.; Uhlig, B.; Schaller, M.; Schultz, S.E.; Röpcke, J.: **Quantum cascade laser based correlation studies in CF4 plasmas for etching ultra-low-k SiCOH materials** 7th IPS, Inuyama/Japan 2016

44. Masur, K. **Kaltes physikalisches Atmosphärendruck-Plasma zur Heilung chronischer Wunden** 26th Conference of the European Wound Management Association, Bremen/Germany, 2016

45. Masur, K. P**lasmamedizin: vom Labor in die Klinik** 10th Int. Symp. on Non-Thermal/Thermal Plasma Pollution Control Technology & Sustainable Energy, Florianopolis/Brazil 2016

46. Methling, R.; Franke, St.; Gortschakow, S.; Abplanalp, M.; Sütterlin, R.-P.; Delachaux, T.; Menzel, K.-O.: **Comparison of Methods of Electrode Temperature Determination in High-Current Vacuum Arcs** 27th ISDEIV, Suzhou/China 2016

47. Methling, R.; Khakpour, A.; Gortschakow, S.; Uhrlandt, D.; Franke, St.; Popov, S.; Batrakov, A.;Weltmann, K. D.: **Investigation of High Current Vacuum Arcs during the Formation of Anode Modes by Time and Space Resolved Spectroscopy** 5th ITG Int. Vacuum Electronics Workshop, Bad Honnef/Germany 2016

48. Methling, R.; Popov, S.; Batrakov, A.; Uhrlandt, D.: **Spectrally and Spatially Resolved Imaging of an Anode Flare in the Initial Stage of a Vacuum Arc Discharge** 27th ISDEIV, Suzhou/China 2016

49. Miron, C.; Sava, I.; Kruth, A.; Quade, A.; Balcerak, M.; Bonislawski, M.; Holub, m.; Weltmann, K.-D.; Kolb, J. F. : **Treatment of polymer films by pulsed electrical discharges in liquids** 4th Int. Workshop on Solution Plasma & Molecular Technology, Pilsen/Czech Republic 2016

50. Moritz, J.; Bekeschus, S.: **Small particle secretion of human leukocytes exposed to exogenous oxidants** 10th Int. Symp. on Non-Thermal/Thermal Plasma Pollution Control Technology & Sustainable Energy, Florianopolis/Brazil 2016

51. Nave, A.; Baudrillart, B.; Hamann, S.; Benedic, F.; Lombardi, G.; Gicquel, A.; van Helden, Jean-Pierre H.; Röpcke, J.: **Spectroscopic study of low pressure, low temperature H2-CH4-CO2 microwave plasmas used for large area deposition of nanocrystalline diamond films** FLAIR, Aix-Les-Bains/France 2016

52. Nave, A.S.C.; Baudrillart, B.; Hamann, S.; Bénédic, F., Lombardi, G.; Gicquel, A.; van Helden, J.H.; Röpcke, J.: **Spectroscopic study of low pressure, low temperature H2-CH4-CO" microwave plasmas used for large area deposition of nanocrystalline diamond films** 7th IPS, Inuyama/Japan 2016

53. Nemschokmichal, S.; Tschiersch, R.; Bogaczyk, M.; Meichsner, J.; Höft, H.; Kettlitz, M.; Brandenburg, R.; Wild, R.; Stollenwerk, L.: **Influence of volume and surface processes in dielectric barrier discharges** Intern. SFB-TR24 Konferenz: Quo vadis - Complex Plasmas, Hamburg/Germany 2016

54. Polak, M.: **Einsatz von Atmosphärendruckplasmen zur gezielten Steuerung der Wechselwirkung von Zellen mit Oberflächen** 26. AK-ADP, Aalen/Deutschland 2016

55. Rödder, K.; Gandhirajan, R.; Bekeschus, S.: **Melanoma viability in co-culture with murine splenocytes following plasma exposure** 5th Young Professionals Workshop on Plasma Medicine, Rostock/Germany 2016

56. Rödder, K.; Miller, V.; Bekeschus, S.: **Cold plasma treatment of murine cancer cells triggers immunogenic responses in splenocytes ex vivo** 6th Int. Conf. on Plasma Medicine, Bratislava/Slovakia 2016

57. Schmidt, A. **Biological effects of reactive species on wound healing in a full-thickness skin wound mouse model** Seminarvortrag

58. Schmidt, M.; Timmermann, E.; Kettlitz, M.; Brandenburg, R.: **Combined electric wind and non-thermal plasma for gas cleaning** 10th Int. Symp. on Non-Thermal/Thermal Plasma Pollution Control Technology & Sustainable Energy, Florianopolis/Brazil 2016

59. Schmidt, M.; Timmermann, E.; Kettlitz, M.; Brandenburg, R.: **Dekomposition von VOCs mit dielektrisch behinderten Oberflächenentladungen** DPG Frühjahrstagung Plasmaphysik, Hannover/Deutschland 2016

60. Schnabel, U.; Stachowiak, J.; Schlüter, O.; Andrasch, M.; Ehlbeck, J.: **Plasma processed water (PPW) - an alternative for fresh-cut salad sanitation?** 18th World Congress of Food Science and Technology (IUFoST2016), Dublin/Ireland 2016

61. Tschiersch, R.; Bogaczyk, M.; Nemschokmichal, S.; Meichsner, J.: **Surface charge measurements on transparent dielectrics in diffuse and filamentary barrier discharges** DPG Frühjahrstagung Plasmaphysik, Hannover/Deutschland 2016

62. Tschiersch, R.; Nemschokmichal, S.; Bogaczyk, M.; Meichsner, J.: **Characterization of self-stabilized single barrier discharge filaments by correlated electrical, optical and surface charge diagnostics** 23rd ESCAMPIG, Bratislava/Slovakia 2016

63. Uhrlandt, D; Baeva, M.: **Analysis of the power budget of TIG arc based on non-equilibrium modelling** 69th IIW Annual Assembly and Int. Conf., Melbourne/Australia 2016

64. van Helden, J. H.; Lang, N.; Nave,A.; Macherius, U.; Zimmermann, H.; Wiese, M.; Röpcke, J.: **Sensitive Spectroscopy of Plasma in the Mid-Infrared Spectral Range** OSA-Meeting MICS, Long Beach/USA 2016

65. van Helden, J.H.: **On recent progress applying cavity-enhanced spectroscopy techniques to characterize atmospheric pressure plasma jets** Intern. SFB-TR24 Konferenz: Quo vadis - Complex Plasmas, Hamburg/Germany 2016

66. van Helden, J.H.; Gianella, M.; Nave, A.; Reuter, S.; Ritchie, G.A.D.: **The detection of the highly reactive HO2 radical and of CH4 in atmospheric pressure plasma jets** 7th IPS, Inuyama/Japan 2016

67. van Helden, J.H.; Gianella, M.; Reuter, S.; Lang, N.; Ritchie, G.; Röpcke, J.: **The detection of the highly reactive HO2 radical and of CH4 in atmospheric pressure plasma jets** OSA Meeting LACSEA, Heidelberg/Germany 2016

68. von Woedtke, Th. **Plasma therapies** 6th Int. Conf. on Plasma Medicine, Bratislava/Slovakia 2016

69. Wende, K. Physical **plasma - creator, destructor, tool. Basics and applications.** 5th Young Professionals Workshop on Plasma Medicine, Rostock/Germany 2016

70. Wende, K. **Cells as biochemical sensor systems do´s, don´ts, risks, & chances,** COST TD1208 Training School, Belgrad, 2016 Seminarvortrag

71. Winter, J. et al.: **Challenges and solutions on the way to a deployable plasma endoscope** 6th Int. Conf. on Plasma Medicine, Bratislava/Slovakia 2016

72. Winter, J.; Hänel, M.; Reuter, S.: **Focal point multipass cell for laser absorption spectroscopy** 7th IPS, Inuyama/Japan 2016

73. Yanai, Y.; Gerling, T.: **PlasmaMedic Ltd. - Combating hospital acquired infections** 4th Annual MedTech & Digital Health Forum, Basel/Switzerland 2016

74. Zocher, K.; Banaschik, R.; Schulz, T.; Miron, C.; Kolb, J. F.: **Enhancement cell wall rupture of microalgae by spark discharges** 13th Int. Bioelectrics Symp., Rostock/Germany 2016

75. Zocher, K.; Banaschik, R.; Schulz, T.; Miron, C.; Kolb, J. F.: **Enhancement cell wall rupture of microalgae by spark discharges** 13th Int. Bioelectrics Symp., Rostock/Germany 2016

# TALKS 2017

1. Andrasch, M.; Stachowiak, J.; Schlüter, O.; Schnabel, U.; Ehlbeck, J.: **Scale-up to pilot plant dimensions of plasma processed water generation for fresh-cut lettuce treatment** 31st EFFoST, Melia Sitges/Spain 2017

2. Andrasch, M.; Stachowiak, J.; Schlüter, O.; Schnabel, U.; Ehlbeck, J.: **Scale-up to pilot plant dimensions of plasma processed water generation for fresh-cut lettuce treatment** 10th Int. FRUTIC Symp., Berlin/Germany 2017

3. Banaschik, R.; Bednarski, P.; Kolb, J.F.; Kredl, J.; Lukes, P.; Schulz, T.: **Sub-microsecond discharges for the degradation of organic pollutants in water** IEEE Pulsed Power Conference 2017, Brighton/ UK, 2017

4. Banaschik, R.; Miron, C.; Jablonowski, H.; Pipa, A.; Fricke, K.; Kredl, J.; Schulz, T.; Weltmann, K.-D.; Kolb, J.F.; Lukes, P.; Bednarski, P.J.: **Plasma-Liquid Chemistry of Pulse Discharges Generated in Water Depending on Pulse Duration and Ground Electrode Materials** ICOPS, Atlantic City, New Jersey USA 2017

5. Bansemer, R.; Schmidt-Bleker, A; van Rienen, U; Weltmann, K.-D.: **Controlling the RONS composition in a handheld plasma source** 23rd ISPC, Montreal/Canada 2017

6. Bansemer, R.;Winter, J.; Nishime, T.;Horn, S.;Glitsch, S.:Lühder,H.; Wende, K.; Szymiczek, D.;Lösche, C.;Scharf, C.:Ehlbeck, J.;Weltmann, K.-D.: **Plasma jets in endoscopic applications** 4th International Workshop on Plasma Science & Entrepreneurship, Orléans/ France, 2017

7. Bekeschus, S.: **Plasmas as Tools in Dermatology and Onko-Therapy** Young Professionals Workshop on Plasma Medicine, Rostock/Germany 2017

8. Bekeschus, S.; Miller, V.; Fridman, A.; Weltmann, K.-D.: **Plasma, Cancer, Immunity - Roads and Challenges** iPlasmaNano conference VIII, Antwerpen/ Belgien, 2017

9. Bekeschus, S.; Rödder, K.; von Woedtke, T.; Weltmann, K.-D.: **Cold plasma provides immune stimulus to battle cancer** ICOPS, Atlantic City, New Jersey USA 2017

10. Bruno, G.; Heusler, T.; Jablonowski, H.; Lackmann J.W.; Wende, K.: **Mass spectrometry based analysis of the oxidation compounds produced by cold atmospheric plasma (CAP) interaction with cysteine** Young Professionals Workshop on Plasma Medicine, Rostock/Germany 2017

11. Clemen, R.; Moll, J.; Scheller, J.: **Building complexes of fluorescent fusionproteins using nanobodies as crosslinking agents** Young Professionals Workshop on Plasma Medicine, Rostock/Germany 2017

12. Ding, J.; Jiang, S.; Kolb, J.; Li, Z.; Rao, J.: **An All Solid-State Nanosecond Pulse Generator for Waste Water Treatment** Proc. of the IEEE Pulsed Power Conference, Brighton/ UK, 2017

13. Freund, E.; Hackbarth, C.; Partecke, L.I.; Bekeschus, S.: **Oxidants increase toxicity and immunogenicity in murine colon cancer cells** Young Professionals Workshop on Plasma Medicine, Rostock/Germany 2017

14. Fricke, K.; Levien, M.; Kredl, J.; Weltmann, K.-D.: **On the Deposition of Bactericidal Copper/Plasma Polymer Composite Coatings by using Atmospheric Pressure Plasmas** 23rd ISPC, Montreal/Canada 2017

15. Fröhlich, M.: **Ökologische und funktionsoptimierte Vorbehandlungskette für die Plasmabeschichtung komplex geformter Schneidwerkzeuge Projekt Öko-Clean Erste Ergebnisse** Arbeitsgemeinschaft INPLAS Neuartige Plasmaquellen und -prozesse, Chemnitz/Germany, 2017

16. Fröhlich, M.: **Technologie mit Perspektive Plasmaprozesse zur Reinigung, Beschichtung und Haftvermittlung** Plasmatechnologie trifft Luftfahrt, ZAL Hamburg/ Germany, 2017

17. Fröhlich, M.; Gauter, S.; Kersten, H.: **Unconventional plasma diagnostic how calorimetric measurements help to understand magnetron sputter processes** 3rd International Workshop on Diagnostic Systems for Plasma Processes, Lichtenwalde/Germany, 2017

18. Fröhlich, M.; Gauter, S.; Kersten, H.: **Unconventional plasma diagnostic how calorimetric measurements help to understand magnetron sputter processes** 3rd International Workshop on Diagnostic Systems for Plasma Processes, Lichtenwalde/Germany, 2017

19. Fröhlich, M.; Ihrke, R.; An, S.; Testrich, H.; Harhausen, J.; Köpp, D.: **Plasmaglätten und Beschichten von 3D-gedruckten Teilen** Gemeinschaftsausschuss Kombinierte Oberflächentechnik, INPLAS, Braunschweig/Germany, 2017

20. Gerling, T.; Brandenburg, R.; Horn, S.; Winter, J.; Weltmann, K.-D.: **Plasmaquellenkonzepte für medizinische Nutzung** Workshop Plasma4Life, Tübingen/Deustchland 2017

21. Gianella, M.; Reuter, S.; Aguila, A. L.; Lang, N.; Röpcke, J.; Ritchie, G. A. D.; van Helden, J. H.: **Detection of HO2 in an atmospheric pressure plasma jet using optical feedback cavity-enhanced absorption spectroscopy** 12th CES, Egmond aan Zee/Netherlands 2017

22. Gött, G.; Gericke, A.; Henkel, K.-M.; Uhrlandt, U.: **What did we learn about the SAW cavern?** IIW Annual Assembly, Shanghai/China 2017

23. Hahn, V.; Winter, J.; Kolb, J.F.; v. Woedtke, Th.; Weltmann, K.-D.: **Decontamination in healthcare with customized low temperature plasma** 18. World Sterilization Congress, Bonn, Deutschland, 2017

24. Hamann, S.; Burlacov, I.; Spies, H.-J.; Biermann, H.; Röpcke, J: **Spectroscopic investigations of plasma nitriding processes: A comparative study using steel and carbon as active screen materials** 18th LAPD, Prague/Czech Republic 2017

25. Harhausen, J.; Foest, R.; Wauer, J.; Baeva, M.; Stenzel, O.; Wilbrandt, S.; Franke, C.; Oberberg, M.; Brinkmann, R. P.: **Prospects for the enhancement of PIAD by plasma diagnostics** SPIE Optifab, Rochester/ USA, 2017

26. Hasse, S. **Einsatz des kINP MED in der Mund-Kiefer-Gesichtschirurgie** ak-adp, 5 Workshop Plasmamedizin, Rostock, Deutschland, 2017

27. Höft, H. **Experimental and modeling results on the axial and radial breakdown dynamics in dielectric barrier discharges** 70th GEC, Pittsburgh/USA 2017

28. Höft, H. **Radiale Entwicklung des Streamerdurchbruchs ingepulsten, dielektrisch behinderten Entladungen** DPG Frühjahrstagung Plasmaphysik, Bremen/ Deutschland 2017

29. Jablonowski, H.: **Nitric oxide in plasma treated buffer solution where is it generated?** 23rd ISPC, Montreal/ Canada 2017

30. Jablonowski, H.; Sousa, J.S.; Schmidt-Bleker, A.; Winter, J.; Wende, K.; von Woedtke, Th.; Weltmann, K.-D.; Reuter, S.: **Plasma generated ozone: Detection from the gas phase to the liquid** International Conference on Plasmas with Liquids (ICPL 2017), Prague/Czech Republic 2017

31. Zocher, K.; Wende, K.; Volzke, J.; Kolb, J.; Weltmann, K.-D.: **Microalgal protein and pigment analysis after extraction spark discharge treatment** 2nd World Congress on Electroporation, Norfolk USA, 2017

32. Khabipov, A.; Kaeding, A.; Hackbarth, C.; Partecke, L.I.; Bekeschus, S.: **Pankreastumorwachstum und Makrophagendifferenzierung Nutzen der Kaltplasma-Therapie im Zellmodell** 10th Int. FRUTIC Symp., Berlin/Germany 2017

33. Khakpour, A.; Methling, R.; Franke, S.; Gortschakow, S.; Uhrlandt, D.: **Emission Spectroscopy During High-Current Anode Modes in Vacuum Arc** 22th Symp. on Physics of Switching Arc, Brno/Czech Republic 2017

34. Kolb, J.F.; Banaschik, R.; Kredl, J.; Schulz, T.; Miron, C.; Lukes, P.; Bednarski, P.J.; Weltmann, K.-D.: **Environmental Applications of Plasmas in Liquids** 2nd World Congress on Electroporation, Norfolk USA, 2017

35. Kolb, J.F.; Brandenburg, R.: **Micro-pollutant Degradation with Pulsed Plasmas** Baltic Clean Technology Conference for sustainable solutions, Rostock/Deutschland 2017

36. Kruth, A.; Foest, R.: **Energy Materials and Surfaces Research at the INP, Reading/UK, 2017** Seminar Johnson Matthey, Reading/UK 2017

37. Lackmann, J.-W.: **Atmospheric Plasmas for Medical Applications in Space** VAAM Fachgruppentagung Weltraummikrobiologie, Köln/Germany 2017

38. Levien, M.; Kredl, J.; Weltmann, K.-D.; Fricke, K.: **Atmospheric pressure plasma-based preparation of antimicrobial polymer coatings with controlled copper release** 28th European Conference on Biomaterials, Athen/ Griechenland 2017

39. Loffhagen, D.: **Kinetische Berechnung der Transportkoeffzienten der Elektronen in CO2** DPG Frühjahrstagung Plasmaphysik, Bremen/Deutschland 2017

40. Masur, K.; von Werde, Y.; Metelmann, H-R.; Schwetlick, B.; Motz, W.; Han, I.; Yi, S.-H.; Choi, E. H.; von Woedtke, Th.; Weltmann, K.-D. **Plasma Medicine: From Bench to Bedside** AVS64th, Tampa/ Florida, 2017

41. Melo, G.P.; Bernardes, S.S.; Neto, F.P.S.; Cecchini, A.L.: **Tumor microenvironment and systemic nitro-oxidative stress during the progression of melanoma pulmonary metastasis** Young Professionals Workshop on Plasma Medicine, Rostock/Germany 2017

42. Miron, C.; Kruth, A.; Weltmann, K. D.; Kolb, J. F.: **Structural modification of polymer nanocomposites treated by plasma in liquids for electroluminiscent devices** Workshop on Advanced Materials Science, Leibniz Association, Dresden/Deutschland 2017

43. Miron, C.; Sava, I.; Hulubei, C.; Quade, A.; Kruth, A.; Bodnar, W.; Burkel, E.; Weltmann, K.-D.; Kolb, J.F.: **Optical and Mechanical Properties of Polymers Treated by Plasma in Liquids** 5th International Workshop and the 4th International Mini Workshop on Solution Plasma and Molecular Technologies, Greifswald/Deutschland 2017

44. Moritz, J.; Marx, S.; Stoffels, I.; Bekeschus, S.: **Exogenous oxidants and macrophage polarization in zumor environment** Young Professionals Workshop on Plasma Medicine, Rostock/Germany 2017

45. Müller, M.-C. Cultivation, **Analytics and Isolation of Cyanobacterial Compounds** Young Professionals Workshop on Plasma Medicine, Rostock/Germany 2017

46. Nebe, J. B.; Finke, B.; Rebl, H.; Moerke, C.; Schnabelrauch, M.; Stählke, S.: **Bioactivation of implant materials and induction of cell signaling via a plasma polymer nanolayer** 28th European Conference on Biomaterials, Athen/Griechenland 2017

47. Peglow, S.; Pohl, M.-M.; Brüser, V.: **Plasma-vapour-deposition synthesis of Au and Au-Ag core-shell nanoparticle on metal oxide semiconductors** 10th Symposium on Vacuum based Science and Technology, Kolobrzeg/Polen 2017

48. Prehn,F.; Timmermann, E.; Hahn, V. **Indoor air purification by dielectric barrier discharge** Young Professionals Workshop on Plasma Medicine, Rostock/Germany 2017

49. Rataj, R.; Kredl, J.; Miron, C.; Schulz, T.; Kolb, J.F.: **Investigations on Corona-like Sub-microsecond Pulsed Discharges in Water** 5th International Workshop and the 4th International Mini Workshop on Solution Plasma and Molecular Technologies, Greifswald/Deutschland 2017

50. Rupp, C.;Hamann, S.; Nave, A.; Burlacov, I; Spies, H.-J.; Biermann, H.; Röpcke, J.: **Spectroscopic studies of active screen plasma nitrocarburizing processes comparing a steel and a carbon mesh as an active screen** DPG Frühjahrstagung Plasmaphysik, Bremen/Deutschland 2017

51. S. Gortschakow **Determination of Cr density in the high-current vacuum arc considering anode activity** 22th Symp. on Physics of Switching Arc, Brno/Czech Republic 2017

52. Schäfer, J.; Fricke, K.; Foest, R.: **Schichtsynthese aus siliziumorganischen Verbindungen mittels eines innovativen Verfahrens: Liquid Assisted Plasma Enhanced CVD** 30. AK-ADP, Jena/ Germany, 2017

53. Schlüter, O.; Adamzig, H.; Cziollek, I.; Ehlbeck, J.; Theilen, H.: **PLASMA-BASED DECONTAMINATION OF DRIED PLANT-RELATED PRODUCTS TO ENHANCE FOOD SAFETY (³PLAS)** 34. Anuga, Köln/Germany 2017

54. Schmidt, A. **Evaluierung des Wundheilungs- und Risikopotentials einer kalten Atmosphärendruckplasmaquelle im dermalen full-thickness Mausmodell** ak-adp, 5 Workshop Plasmamedizin, Rostock, Deutschland, 2017

55. Schmidt,M.; Gerber, I. C.; Gerling, T.; Altrock, B.; von Woedtke, T.: **Pin-to-liquid discharge: optical, electrical and chemical characterization and application** DPG Frühjahrstagung Plasmaphysik, Bremen/Deutschland 2017

56. Schnabel, U.; Stachowiak, J.; Schlüter, O.; Andrasch, M.; Ehlbeck, J.: **Plasma processed water (PPW) an alternative for fresh-cut salad sanitation?** 10th Int. FRUTIC Symp., Berlin/Germany 2017

57. Seebauer, C.; Hasse, S. **Wertigkeit von kaltem physikalischem Plasma in der Behandlung der Leukoplakie als intraorale Präkanzerose** 67. Kongress der Deutsche Gesellschaft MKG, Bonn, Germany, 2017

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1. Steuer, Anna: **Effekte von Nanosekunden gepulsten elektrischen Feldern auf Zellen im Monolayer** University of Rostock 08.06.2016

## PHD THESIS 2017

1. Banaschik, Robert: **Abbau pharmazeutischer Rückstände in Wasser unter Einwirkung gepulster Atmosphärendruckplasme** Ernst Moritz Arndt University of Greifswald 01.3.13 - 01.3.17

2. Hohmann, Jan-Niklas: **Investigation on the influence of plasma treated exsudates - Foccusing on MMPs, TIMPs and cytokines** Ernst Moritz Arndt University of Greifswald 04.04.-30.09.2017

3. Meder, Tida: **Plasma-treated 3D tumor cells role of ambient air and melanoma cell phenotype (med.)** Ernst Moritz Arndt University of Greifswald 04.04.-30.09.2017

4. Nave, Andy: **Physico-chemical investigation of plasma induced deposition processes** Ernst Moritz Arndt University of Greifswald 01.09.2013 - 6.10.2017

5. Segebarth, Maria: **Einfluss von kaltem Atmosphärendruck-plasma auf chronisch-entzündliche Mundschleimhauterkrankungen mit besonderem Augenmerk auf die lokale Immunantwort (med)** Ernst Moritz Arndt University of Greifswald 01.01.-31.12.2017

6. Vu, Uyen My: **Molekularbiologische Untersuchung Plasma-induzierter Effekte im Wundmodell der Maus** Ernst Moritz Arndt University of Greifswald 02.04.-30.09.2017

7. Wulf, Can Pascal: **Differenzierungsverhalten von Monozyten nach Stimulation mit Plasma-behandelten Ovarialkarzinomzellen, (Dr. med.)** Ernst Moritz Arndt University of Greifswald 01.04.2017 - 29.09.2017

## DIPLOM AND MASTER THESIS 2016

1. Dorst, Johanna: **Deposition and characterization of functional plasma polymer nanofilms** Ernst Moritz Arndt University of Greifswald 1.10.2015-6.10.2016

2. Klink, Rouven: **Untersuchung des Einflusses dielektrischer Oberflächen auf das Verhalten von Barrierenentladungen** Ernst Moritz Arndt University of Greifswald 01.11.2015 - 02.11.2016

3. Leskow, Fabian Hagen: **Konzeption und Aufbau einer Vorrichtung zur Detektion von Milben auf Honigbienen** FH Stralsund 17.07.2017

4. Moritz, Juliane: **Kleinpartikel-Analyse humaner Leukozyten nach Behandlung mit physikalischem Kaltplasma** Ernst Moritz Arndt University of Greifswald 13.04.2015 - 29.07.2016

5. Näser, Freya: **Einfluss von physikalischem Plasma auf das Proteom und die Produktbildung von Ganoderma lucidum** Ernst Moritz Arndt University of Greifswald 01.01-17.10.2016

6. Schlewitt, Mathias: **Untersuchung und Minimierung der Störeinflüsse durch Schaltnetzteile (SNT) auf Stromtreiber und Temperaturcontroller zum Betrieb von cwQCLs** FH Stralsund 13.04.2016

7. Schult, Kathleen: **Untersuchungen ZUR Wirkung von kaltem Atmosphärendruckplasma und Doxorubicin auf Mammakarzinomzellen** Ernst Moritz Arndt University of Greifswald 23.03.2016

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1. Altrock, Beke: **Untersuchung des Einflusses von Proteinen auf die antimikrobielle Wirksamkeit von Plasma-aktivierter physiologischer Kochsalzlösung** Ernst Moritz Arndt University of Greifswald 16.06.2017

2. Apelmann, Marie: **Generierung antimikrobieller Oberflächen für medizinische Anwendungen mittels atmosphärischen Plasmaspritzens (APS) ultrafeiner Pulver** University of Rostock 10/2016-06/2017

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