BIENNIAL REPORT 2018/2019

LEIBNIZ INSTITUTE FOR PLASMA SCIENCE AND TECHNOLOGY

FROM IDEA TO PROTOTYPE

MicroQuasar by Laura Barillas-Mora

INP
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Physical plasma is highly versatile and offers effective solutions in many areas of life and for current social challenges. There is enormous potential, especially in combination with specialist disciplines, such as the life sciences or engineering sciences. At the INP, we want to continue to harness this potential.

On the following pages, we present our research work in application-oriented fundamental research in the highly versatile field of plasma technology. As a research institute of the Leibniz Association, we are constantly crossing the boundary between fundamental and applied research. At the first glance, this is not always easy to reconcile, especially because the combination of different competences is absolutely necessary. However, the experience of recent years has shown us that it is precisely this tension that produces the best ideas for shaping innovative research disciplines such as plasma medicine and plasma agriculture.

You will also find details of the various activities in our research divisions Materials & Energy and Environment & Health. We have dedicated special sections to particular highligths, such as the two projects "Campfire" and "Physics for Food", which were started within the framework of the WIR funding guidelines of the BMBF, news from the "Karlsburg Diabetes Centre of Excellence", or the start of the new construction of the Centre for Life Science and Plasma Technology in Greifswald.

Interdisciplinarity and lateral thinking coupled with a willingness to take risks is what sets INP researchers apart. We owe our success to committed employees and solid support from our sponsors and partners from various sectors. We are therefore more than just a little proud of the achievements we have made in the last two years. We are also well-equipped to take on future challenges. We hope you enjoy reading this report. We hope that you continue to accompany us on our exciting journey.

Prof. Dr. Klaus-Dieter Weltmann
Chairman of the Board and Scientific Director

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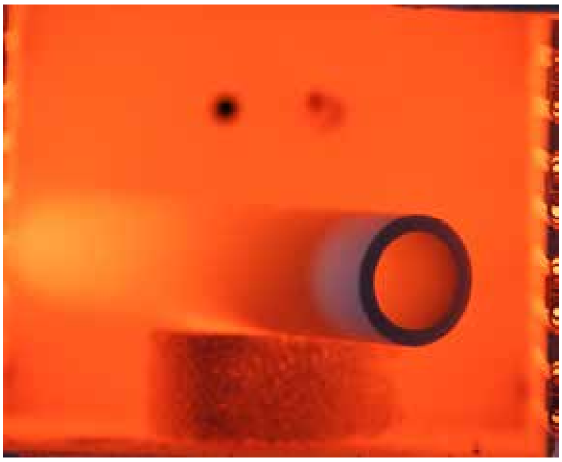
Green ammonia for emission-free mobility – the Campfire research alliance

Within the framework of the pilot programme "WIR! – change through innovation in the region" of the BMBF, the CAMPFIRE alliance has started its work under the leadership of INP in 2019. The aim of the research and industrial partners is to establish a promising new economic sector in the project region North-East of Germany by developing innovative energy technologies and by interlinking the local energy sector with the maritime and chemical industry. The core of this research is the decentralised production of green ammonia from renewable energies. This is based on years of preparatory work by INP in the field of hydrogen technology. In parallel to the current research work, technological-economic studies for the sustainable production of the material and its use as fuel in shipping are being carried out. Ammonia is an excellent carbon-free energy storage, can be easily liquefied, and has a high energy density, thus making it attractive for use in zero-emission drives.



"Physics for Food – a region is changing its way of thinking!"

Through the use of innovative physical technology, the project "Physics for Food – a region is changing its way of thinking" aims to shape structural change in the "coastal hinterland North-East" region, which is characterised by the traditional agriculture and food industry. Based on current ecological, economic, social, and political challenges, various innovation potentials are being pursued. These include the replacement of active chemical ingredients in agricultural plant protection and strengthening plant health in order to maintain and increase yields under changing environmental conditions. The project is flanked by an integrated technology transfer geared to the social values of regional and sustainable agriculture. The INP is a partner in this alliance project, which is also part of the "WIR! – change through innovation in the region" pilot programme. This funding is an important milestone in the expansion of plasma agriculture at INP. The expansion will also be accelerated by the experience and scientific knowledge gained in the field of plasma medicine.

New spin-off with an award-winning idea – Nebula Biocide GmbH

Researchers at INP have invented a completely new hand disinfection process and were awarded the "Inno Award" in 2018 and in June 2019 in the ideas competition of the healthcare industry in Mecklenburg Western-Pomerania. On this basis, Nebula Biocide GmbH – now the fifth spin-off from our institute – was founded.
The company's patented process has decisive advantages over conventional substances for hand disinfection used in hospitals, medical practices, and public toilets. It consists of water, is odourless, protects hands and the environment, and does not produce any chemical residues. The innovative disinfectant is also much more effective because it also kills bacterial spores (formed by clostridia among others) within a few seconds.

These encapsulated and heat-resistant permanent forms of the bacteria have become a problem in hospital hygiene. Patients are additionally weakened by the toxins released. If the new hand disinfection method was used on a large scale, this could significantly reduce the risk of infection in hospitals and public facilities (e.g. shopping centres).

INP scientist Dr. Jens Harhausen honoured with "Hans Pulker Award"

In 2018, the Hans Pulker Award of the International Conference on Coatings on Glass and Plastics (ICCG) was awarded for a joint project of the INP, the Fraunhofer Institute for Applied Optics and Precision Engineering, and the University of Bochum. A jury of the International Organizing Committee awarded the paper "Novel concepts for in situ characterization and control of plasma ion assisted deposition processes" by the authors J. Harhausen, R. Foest, O. Stenzel, S. Wilbrandt, C. Franke and R. P. Brinkmann as "best paper". The work investigates so far only insufficiently known parameters of coating plasmas and derives strategies to improve the deposition processes widely used in industry.

Karlsburg Diabetes Centre of Excellence starts operation

The Karlsburg Diabetes Centre of Excellence (KDK) stands for innovative medical technology and application-oriented research. Here, innovative diagnostic and therapeutic options in the field of diabetes and wound healing are developed in a unique way. The centre was officially opened in November 2018. The pioneering concept developed in 2012/2013 is based on three pillars: research, development, and transfer to industrial and medical practice. The clinical treatment of diabetes patients as well as interdisciplinary and practice-oriented research will take place in appropriately equipped laboratories in the immediate vicinity. As a result, research results can be transferred much more quickly into clinical application in cooperation with companies from the medical sector. This will greatly benefit patients. The Karlsburg Diabetes Centre of Excellence was funded by the Ministry of Economics, Employment and Health of the state of Mecklenburg-Western Pomerania and the EU with approximately €2.5 million. The centre is a cooperative initiative of the Karlsburg hospital and the INP.

Photo of the construction of the future centre for Life Science and Plasma Technology (C4LP) in Greifswald. Completion is planned for 2022.

Outlook

Through numerous projects, the Leibniz Institute for Plasma Science and Technology (INP) has proven that there is great economic potential in plasma technology applications and that innovative solutions to socially relevant problems can be found. We work closely with industry and other research institutions. The cooperations with research institutions and industrial partners are an essential component for future projects. The following examples should give a small insight into our research spectrum for the coming years.

Our contribution to energy transition

Together with the Leibniz Institute for Catalysis (LIKAT, Rostock) and the Fraunhofer Institute for Large Structures in Production Engineering (IGP, Rostock), we at INP want to play a pioneering role in the development of cost-effective and efficient hydrogen technologies. To this end, we want to establish a research factory for the production of hydrogen (H_2), ammonia (NH_3), and CO_2-neutral carbon-based fuels (such as synthetic methanol or green kerosene).

In Mecklenburg-Western Pomerania, energy production based on wind power, solar technology, and biomass is continually being expanded. A critical point is the lack of systems for producing alternative storage media.
Hydrogen and ammonia, which can be produced with green electricity from wind and/or solar energy, are ideal for this purpose.

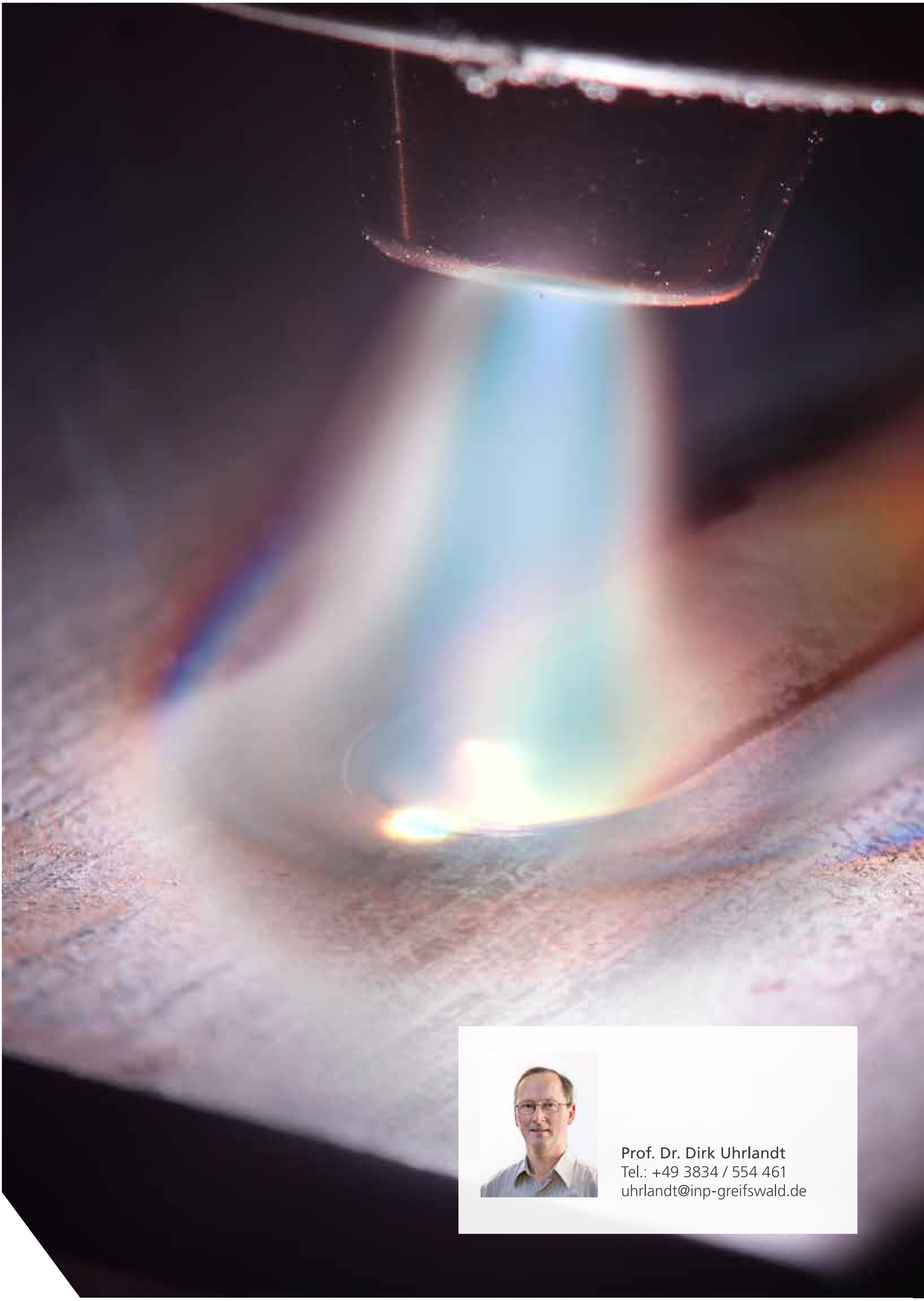
Plasma in agriculture

Our work in the agricultural sector has opened up a completely new field of application for INP. The aim of our researchers is to improve the resistance of plants and to achieve increased growth and higher yields. For example, a central topic is the use of plasma-based technologies instead of chemical treatment to make seeds more durable and more germinable. A further positive effect of plasma treatment is the stimulation of germination even of plant species for which the germination capacity is rather low so that "old varieties" can be more easily produced again.
As EU regulations on plant protection products and general climate change become even stricter, the use of plasma technology represents an attractive alternative to conventional chemical-based treatment methods.

Centre for Life Science and Plasma Technology – room for innovation

The Hanseatic City of Greifswald is investing around €37.6 million in the construction of a Centre for Life Science and Plasma Technology. It is the largest project the municipality has ever undertaken. The Federal State will provide half of this amount through subsidies. Completion is scheduled for Spring 2022. Around 240 new jobs are to be created in the complex, and we would like to make an important contribution to this. In the presence of Chancellor, Dr. Angela Merkel, State Minister of Economics, Employment and Health, Harry Glawe, and the Lord Mayor of Greifswald, Dr. Stefan Fassbinder, the symbolic foundation stone was laid on 4 February 2020. The Centre for Life Science and Plasma Technology, a new research and start-up centre with international appeal, is being set up directly adjacent to the INP. The new building gives our scientists even more opportunities to cooperate with industry and develop prototypes for the market. The INP will therefore lease e.g. an eight-meter-high pilot plant hall, numerous offices, and specially equipped laboratories.

At the INP, we are looking forward to the new opportunities that the centre will provide and are counting on new impulses that the cooperation with regional, national, and international partners will bring, especially in the area of application-oriented fundamental research. The success we have achieved in the past will continue to result in new processes and prototypes. We have set the course for this. We look forward to continued success together with you.



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RESEARCH DIVISION

MATERIALS & ENERGY

Overview

The Research Division combines plasma technology topics in the fields of energy and production technology. Current areas of application are the production of functional coatings, thin films and catalytically active materials using plasma processes as well as plasma chemical synthesis and the use of arcs in energy technology and process engineering.

The focus is particularly on the technical challenges of energy transition. Research is being conducted into new materials for battery technology and photovoltaics as well as the synthesis and storage of hydrogen. It is also a matter of increasing the performance and reliability of the energy infrastructure with new components. Researchers are currently investigating how surfaces can be treated using non-thermal plasmas at atmospheric pressure. The interaction of thermal plasmas with electrodes and walls is also being investigated. Another focus is the development of measuring methods for various applications – from vacuum processes to arc welding. This enables the analysis of the underlying physical and chemical processes.

Research programme materials and surfaces

- Functional films, additive manufacturing
- CarMON (Leibniz competition) – new carbon-metal hydrides

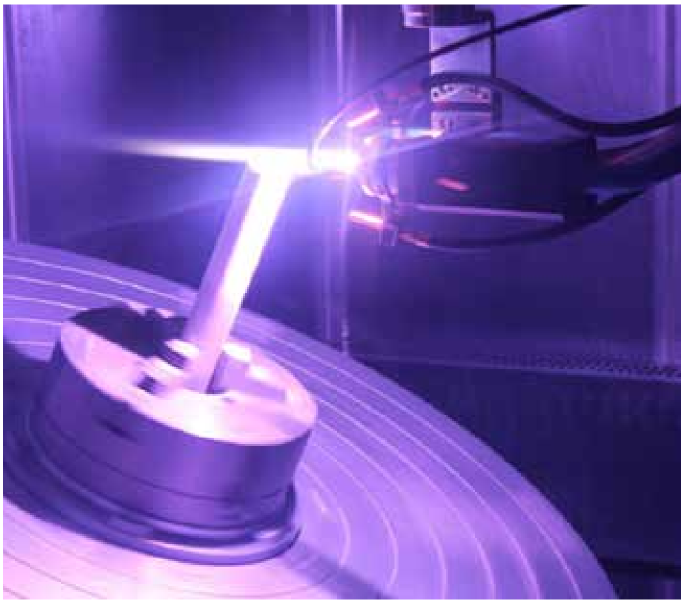
Research programme plasma chemical processes

- Plasma chemistry
- "ReDBirD" – discharge regimes in dielectric barrier discharges for coating

Research programme welding and switching

- Study of the current path in gas metal arc welding for the generation of a dynamic, phenomenological system model
- Electric arcs
- Third-party funded project: use of optical sensor technology for the characterisation of emissions and process stability in gas metal arc welding

Overview



Coating process: Ceramic and metallic films by thermal atmospheric pressure plasma spraying

In sectors, such as nanotechnology, surface and thin-film technology, storage, and the conversion of renewable energies, plasma-assisted processes are indispensable for structured material removal, the production of high-quality coatings, innovative materials, and the adjustment of surface properties. Plasma processes offer a number of engineering advantages such as low thermal load of the components, comparative environmental compatibility, precise control, and a negligible impact on the properties of the base material.

In this research programme, innovative plasma processes are investigated, and technical plasmas are applied, experimentally characterised, simulated, and considered in connection with the film and surface properties. Knowledge of the processes taking place in the plasma ultimately leads to production processes that can be better controlled and thus to superior products.

FIELDS OF APPLICATION

The synthesis of nanostructured materials or nanoparticles using plasma processes opens up perspectives in the field of storage and conversion of renewable energy. These include components, membrane and electrode materials for electrocatalysis (battery and fuel cell technology), or hydrogen technology.

Plasma processes offer new possibilities in the production of materials for energy storage/conversion (e.g. components) and functional films for electrocatalysis (battery and fuel cell technology), in the synthesis of catalytic surfaces for decentralised energy supply (using hydrogen and hydrogen-containing chemical compounds), or in the field of electromobility. Plasma processes can also be used in related fields such as sensor technology and chemical synthesis as well as in water and gas purification and treatment processes.

Further fields of application of thin films open up according to the special functions: hard coatings increase the strength of cutting tools. For tribologically stressed components, they reduce mechanical abrasion. For metals, they reduce the tendency to corrosion and improve protection against thermal and mechanical stress. They improve the adhesion of material composites, have a decorative character, reduce gas permeation, and generate energy (e.g. solar technology). In semiconductor technology and photonics, coatings take on functions as a dielectric, EMC shielding, or optical interference film in the fields of telecommunications, imaging, laser applications, and measurement technology.

In additive manufacturing, the surface finish of metallic 3D printed components can be improved by means of electrolytic plasma polishing. This method also allows the conformal removal of impurities on surfaces.

Application-oriented outlook

The synthesis of materials for renewable energy sources and catalytic processes is a central research topic. As part of the BMBF programme 'Change in the Region' (WIR!), the CAMPFIRE alliance was launched in 2019 in the North-East region (approx. 30 regional and supraregional partners). CAMPFIRE is dedicated to the decentralised production of ammonia from renewable energies and its use as an innovative energy source for emission-free maritime mobility: as fuel in engines and fuel cells. At the INP, the production of thin-film membranes is being researched with the aim of making these usable for the production of ammonia from atmospheric nitrogen and water by electrolysis. The thin-film membranes are manufactured using a plasma-assisted film deposition process. The application of a laser annealing process aims at generating the desired film structures (e.g. ABO3 perovskite structures) on ceramic and metallic substrates.

Further application-oriented activities for the deposition and synthesis of nanodimensional, metallic, metal oxide, and graphitic particles and thin films are linked with applications as platinum- and nickel-based catalysts, membrane and electrode materials for electrocatalysis, and hydrogen technology. Atmospheric pressure plasma processes in liquids are also being investigated for nanoparticle synthesis of these materials.

The electric mobility sector is addressed by the PRISMA project (ERDF), which was launched in 2019. Together with three partners, the INP conducts research on electric car heaters. The core component uses thin-film structures for heating. This allows the high-voltage components in electric vehicles to be used at their optimum operating point. The INP is investigating atmospheric pressure plasma spraying as a manufacturing process for the thin ceramic and metallic films of the heating module. Optical methods are used to characterise the plasma properties and visualize the film growth. The experiments are supplemented by simulations and combined to form a well-founded picture of the plasma process with the aim of improving process monitoring and control.

In the joint project Plasfaser (started in 2017), new approaches for the production of optical fibres for high-power lasers are being pursued. The material deposition for doping the quartz glass is performed by microwave plasmas under normal pressure conditions. In the research programme, plasma diagnostic methods are used and supplemented by simulations in order to better understand the chemical and physical processes taking place in the plasma. The optimal process conditions form the basis for the production of new glass materials at the Leibniz Institute of Photonic Technology in Jena for use in laser applications and telecommunications.

The recent publication of the joint project PluTO+ on the subject of precision thin-film optics formulates control concepts for coating processes based for the first time on quantitative information about the plasma. It was awarded the Hans Pulker Prize (J. Harhausen et al., Thin Solid Films 673 (2019) 94–103). The coatings have potential for photonic applications in sensor technology. Coatings with innovative properties (e.g. smart coatings, integrated optics, and nanoscale modified structures) will become even more important.

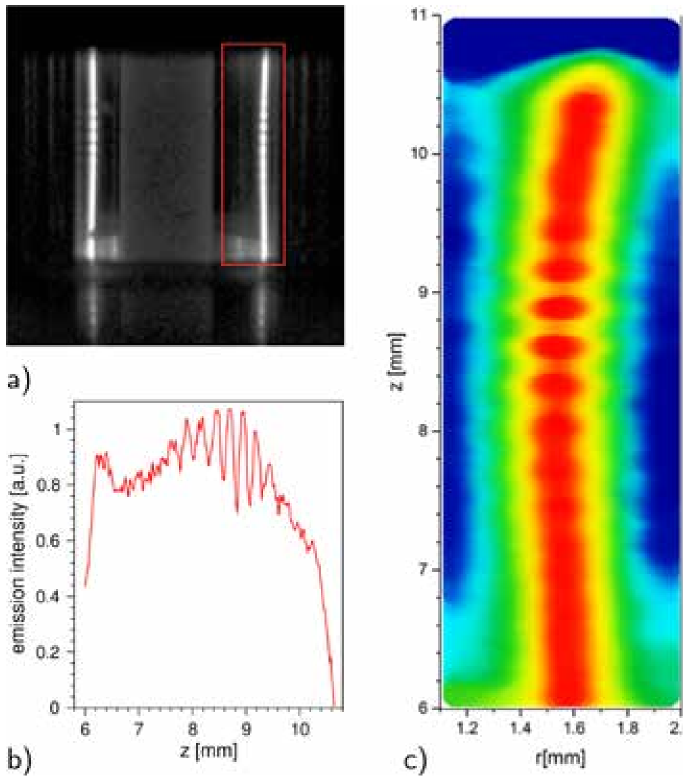
Production of a nanocomposite film using the PVD process

Core-funded project "Functional films"

The work is dedicated to the study of the spatial and temporal behaviour of a non-thermal atmospheric pressure plasma jet (ntAPPJ) and its influence on the reactive deposition of functional films by PECVD (Plasma Enhanced Chemical Vapour Deposition). The gas dynamics of the ntAPPJ leads to self-organization of the discharge filaments and is advantageous for an increased quality of the coating (e.g. carbon-free silicon dioxide film, J. Schäfer et al., Plasma Phys. Control. Fusion 60 (2018) 014038).

The behaviour of a ntAPPJ (Ar, 27.12 MHz) was characterised using a phase-resolved, spatially two-dimensional fluid model, which takes into consideration gas flow and heating in the active zone between the electrodes and the outflowing jet (effluent). In particular, the model shows spatial structures of the discharge filaments of the active zone, so-called striations, which have already been observed experimentally. The results illustrate the influence of the gas flow on the formation of the discharge structures between the electrodes. The striations occur with higher amplitude mainly on the inflow side and relax in the axial direction with the flowing gas. The characteristic dimensions (period length) of the striations correspond quite well with the experimental observations (Fig.). As expected, the particle densities in the volume remain unaffected by the RF period. Only the electron density in the sheath (0.1 mm) is modulated (Sigeneger et al., Plasma Sources Sci. Technol. 28 (2019) 055004).

Research was also carried out with regard to the qualification of a suitable atmospheric pressure plasma for the topic of additive manufacturing/3D printing. These led to the introduction of a new plasma source (helix jet). This is a non-thermal, capacitively coupled RF discharge with a double helix configuration of the electrodes, which generates a stable and spatially homoegenous, filamentless plasma. For the purpose of 3D printing, PA12 powders were added and deposited at a typical deposition rate of 200 mg/s. Static deposition profiles show a Gaussian shape. The deposited material is characterised by strongly interconnected particles and promotes high mechanical stability because of its structure, chemical composition and morphology. (Schäfer et al., Plasma Process Polym. 17 (2020) e1900099).



Atmospheric-pressure plasma: Structured discharge filament (striations) in experiment (a) and in the fluid model (b,c) (Sigeneger et al., Plasma Sources Sci. Technol. 28 (2019) 055004)

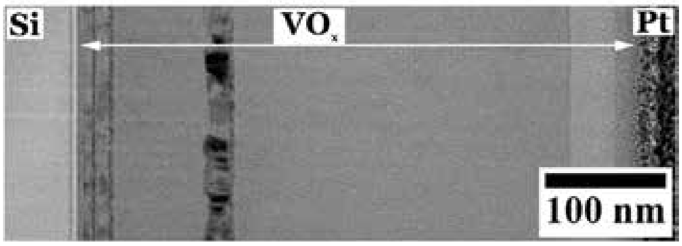
Third-party funded project CarMON (Leibniz competition)

With regard to energy transition in Germany, the storage of electrical energy is one of the key technologies for the 21st century as well as one of the most important scientific, social, and economic problems. In the joint project CarMON, launched in 2017 as part of the Leibniz competition, new carbon-metal nanohybrids for efficient energy storage and water desalination are being developed together with the partners Institute for New Materials in Saarbrücken (INM) and Max Planck Institute for Iron Research in Düsseldorf (MPIE).

The Leibniz competition addresses the strategic goals of the Leibniz Association within the framework of the Pact for Research and Innovation.

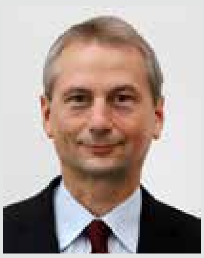
The goal of CarMON is to optimise the bulk and interfacial properties of nanohybrids during synthesis by means of process control and monitoring at the nanoscale. In CarMON, a unique combination of precise plasma synthesis, innovative transmission electron microscopy, and state-of-the-art electrochemical energy storage and water desalination opens up a new interdisciplinary research approach for the synthesis of high-performance materials. Vanadium oxide plays a central role in CarMON as the battery material of the future. Because of its crystal structure, it is particularly suitable as cathode material for Li-ion batteries and super capacitors. At the INP, vanadium oxide is synthesised in form of thin films by means of plasma ion assisted deposition (PIAD). The influence of plasma properties on structural properties and the resulting electrochemical performance is investigated.

Optical spectroscopy and ion-kinetic methods are used as *in situ* plasma diagnostics methods. By means of Retarding Field Analyser (RFEA), the ion currents and energies in the reaction volume are determined. The results suggest that the crystallinity of γ-V_2O_5 can be precisely controlled as a function of the process parameters. This will enable new routes for the synthesis of structured and graduated thin films and open up a new class of nanohybrid coatings consisting of amorphous and electrically conductive single crystalline domains. In addition to energy technology, these films can also be used in Smart Windows and solar cells.



Vanadium oxide: Battery material of the future, film cross section: Formation of monocrystalline γ-V_2O_5 bands in amorphous VOx matrix [TEM image: A. Frank, C. Scheu, MPIE].

CONTACT



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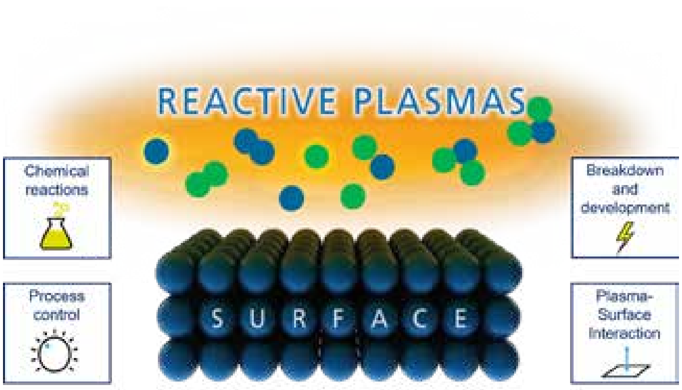
Overview



Questions and core topics of the research programme Plasma Chemical Processes

The research programme Plasma Chemical Processes deals with the physics and chemistry of reactive plasmas. In addition to the chemical processes in the volume and on the adjacent surfaces, the work focuses on correlating these with discharge physics as well as methods for controlling and monitoring.

The projects are clustered around three core topics, namely

- Atmospheric-pressure plasma processes
- New diagnostics and new radiation sources for absorption spectroscopy
- Development of *in situ* process control methods, including their transfer to industrial practice. The research programme makes use of the expertise in high-sensitivity laser absorption spectroscopy as well as in high-resolution imaging and spectroscopy. This includes the determination of the concentrations of the plasma components as well as the analysis of the radiation emitted by the plasma. In addition to the most modern methods of IR spectroscopy, the spectral range could be extended considerably in recent years and ranges now from the THz to the UV range. The research programme closely links its experimental work with the simulation of processes in reactive plasmas.

Fields of application

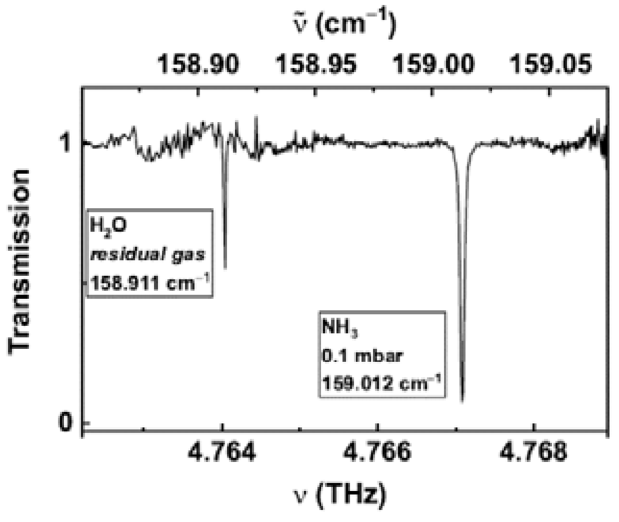
Atmospheric pressure plasma reactors:
Plasmas that can be handled without complex vacuum technology are relevant for many industrial processes. New application potentials are seen in the synthesis of chemical substances and surface treatment (e.g. coating). Our methods of imaging and spectroscopy make it possible to analyse the electrical breakdown and make statements about plasma parameters. These findings show how reactor geometries can be designed and optimised in order to achieve more stable and efficient treatment results. Cavity-enhanced laser spectroscopy also provides a completely new approach to the spatially resolved measurement of reactive and stable species, especially in small-scale plasmas typical for the pressure range.

Process control in industrial plasma processes:
Reactive plasmas are used for activation, cleaning, coating, and etching. The empirical determination of process parameters is increasingly reaching its limits and requires sensitive methods for instantaneously determining the chemical composition of the plasmas and their parameters. IR absorption spectroscopy with quantum cascade lasers is one of the most sensitive methods for chemical plasma analysis. In addition, methods of THz spectroscopy for the detection of atomic species and cavity-enhanced absorption spectroscopy for molecular species are currently being developed.

Plasma nitriding:
Plasma nitrocarburising is one of the most important methods for increasing the surface hardness of work pieces. It reduces the abrasive, adhesive, and corrosive wear of these work pieces. Together with the TU Bergakademie Freiberg, INP is developing an improved process (Active Screen Plasma Nitriding) with a carbon lattice. The grid prevents the formation of arcs and other edge effects and thus enables a more uniform processing of the work pieces. The work is initially aimed at measuring the stable plasma products, the occurrence and concentration of which should be correlated with the surface properties obtained. A frequency comb system is also used for diagnostics. This enables the simultaneous acquisition of several species.

Application-oriented outlook

Plasma-assisted techniques for the treatment of flowing gases are currently used in exhaust air purification. However, their use in chemical synthesis processes has so far hardly gained any significance apart from ozone synthesis. The work in this research programme aims to establish new methods for direct plasma-assisted and plasma-catalytic processes for the production of basic chemicals from simple raw materials with improved selectivity and energy balance. For the production of chemical substances, carbonaceous or other starting materials are to be converted under the influence of a plasma. This will result in chemical compounds that serve as raw or starting material for further processes. Plasmas offer the special possibility of producing short-lived (because reactive) chemical substances efficiently and "on demand" on site using electrical energy from inexpensive source materials.



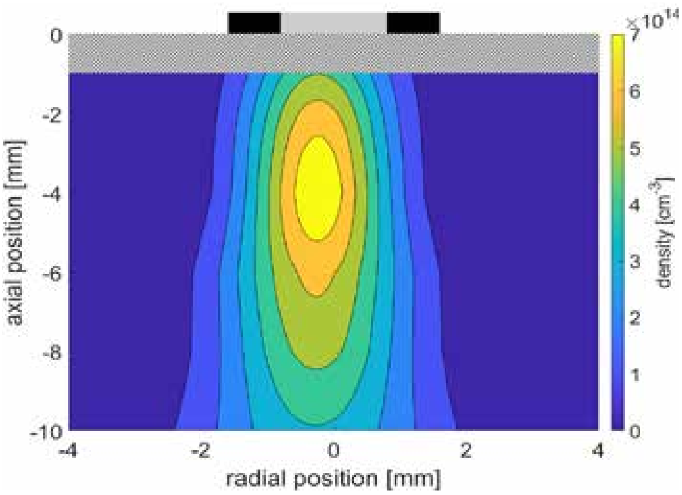
Absorption spectrum of ammonia as reference molecule in the range around 4.767 THz using a novel quantum cascade laser of a 15 cm long absorption cell (collaboration with the Paul Drude Institute Berlin)

In addition to chemistry in gas volumes, surface treatment processes that do not require complex vacuum technology are becoming increasingly important.

In order to safeguard the basic technical capabilities of various metallic components, their surfaces must satisfy strict requirements with regard to wear and/or corrosion. Plasma-assisted thermochemical surface layer treatment can be used to improve surface properties by diffusing nitrogen and carbon into the boundary layer of highly stressed metallic components. Conventional plasma nitrocarburising methods use gaseous carbon precursors in addition to nitrogen and hydrogen. However, these are severely limited with regard to the amount of reactive gases that can be generated. These are the prerequisite for successful thermochemical treatment and thus show limitations in the property profile that can be adjusted within the metallic surface. The aim of the work in the research programme Plasma Chemical Processes is to establish a new plasma-assisted technology for nitrocarburising the surfaces of metallic components. This technology is able to generate novel, defined adjustable chemical gradients within the boundary layer (even allowing the treatment of bulk material) and is therefore much more efficient and economical than currently available technologies.

In addition to the plasma nitrocarburising methods, there are many industrial processes that require sensitive in situ process diagnostics. Also in the context of Industry 4.0 there will continue to be a need for specified measurement techniques. Increasingly complex manufacturing technologies can no longer be sufficiently optimised by simply empirically determining process parameters and statistically modifying them. By using classical IR absorption spectroscopy in the mid infra-red (MIR) and the new cavity enhanced absorption spectroscopy, methods are available to measure the concentration of key species or unwanted impurities down to the ppt range. In combination with plasma simulation, optimisation potentials can be shown. by an increased understanding of the processes, plasma processes can be developed and optimised in a more targeted manner.

Core-funded project "Plasma chemistry"



Profile of the distribution of the radical HO_2 in the effluent of a plasma jet (Klose et al., in preparation for Plasma Sources Sci. Technol.)

The research programme Plasma-chemical processes is based on the successful work of the former research programme Plasma Monitoring, in which primarily new diagnostic methods based on MIR laser absorption spectroscopy were developed for the detection of radicals and stable species and applied to different plasma sources. With the Optical Feedback Cavity-Enhanced Absorption Spectroscopy (OF-CEAS) method, an even more sensitive method has now been introduced. This can even be used in a spatially resolved manner on small-scale plasmas (e.g. the atmospheric pressure plasma jet KinPen) to determine species concentrations. For example, it was possible to determine the hydroperoxyl radical in its effluents. Since then, the use of cavity-based laser absorption spectroscopy has been consistently pursued in order to be able to detect further species in the KinPen. A Cavity Ringdown Spectroscopy thus allows the axial and radial measurement of the effluent for this radical and of hydrogen peroixide as a further key species to explain oxidative effects.

The activities of recent years have also included the use of new radiation sources for laser absorption spectroscopy and have extended the frequency range well beyond the MIR region. As a new radiation source, a frequency comb system was set up in cooperation with the University in Torun (Poland). Optical frequency comb (FC) systems based on fibre-coupled femtosecond lasers are ideally suited for spectroscopic applications. The instantaneous spectrum of a frequency comb consists of a series of equidistant laser lines with precisely known frequency spacing. An FC system thus replaces several thousand individual lasers in one compact system. The spectral bandwidth of typically a few 100 nm allows the simultaneous detection of several species in the plasma. A pioneering role can be taken, especially for applications of molecular spectroscopy based on FC systems in plasma technology. The FC system is currently being used to investigate the plasma nitrocarburising process.

THz spectroscopy is currently being developed as another method. Special quantum cascade lasers can generate THz radiation, which is absorbed by metal atoms and ions in the ground state. This is intended to create a new diagnostic approach for the control of coating processes (e.g. for the deposition of AlN films).

The work in the research programme Plasma Chemical Processes is characterised by a close coupling between experimental work and plasma simulation. In addition to the chemical processes, the processes involved in the formation of the plasmas, especially the electrical breakdown, are also of interest. In atmospheric pressure plasmas, this usually takes place in channels, the so-called streamers. Because of the short duration and high complexity, the essential plasma parameters are almost only accessible by means of simulations. Many approaches have been taken in recent years. In collaboration with five other teams, INP contributed to the validation and verification of plasma models and their limits for describing the physics of the streamers.

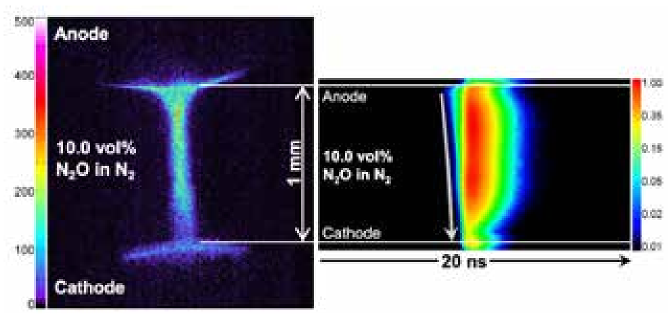
Third-party funded project "ReDBirD"

In the ReDBirD project (Discharge Regimes in Dielectric Obstructed Discharges for Coating) the development and formation of non-thermal atmospheric pressure plasmas are being investigated for surface coating applications.

Plasma processes are state of the art in coating but are usually operated as low-pressure processes. This entails high system costs and prevents "in-line treatment". Plasmas at atmospheric pressure (e.g. dielectric barrier discharge) do not have these disadvantages but usually form a non-uniform plasma with several thin discharge channels. This results in inhomogeneous coating results. The generation of diffuse discharge regimes has also been known for about 20 years. However, this succeeds only under selected operating conditions. Especially in gas atmospheres with precursor molecules, an understanding of the discharge physics and the elementary processes that enable diffuse discharges is still lacking. Reversely, a change in the surface properties during the coating process leads to a change in the plasma parameters. Thus, the control of the processes is still difficult, particularly at high power levels.

As part of the project, the different discharge regimes (single filaments and diffuse discharges) are investigated under process-relevant operating conditions using systematically established electrical, optical, and spectroscopic methods. The project is funded by the DFG and is a collaboration with the working group of Nicoals Naude at the LAPLACE Laboratory of the University Paul Sabbatier in Toulouse. The discharge arrangement of the French partner has a structured electrode that allows the study of collective surface effects and radial discharge dynamics. The work at the INP focuses on discharge physics in miniaturised single discharge arrangements. In particular, the influence of nitrous oxide as a component that simulates the influence of precursors or serves as an oxygen donor in coating processes is considered. One of the discharge arrangements generates the single discharge on a liquid dielectric on which the surface charge is to be minimised and thus decoupled from the plasma chemical volume processes.

In the single discharge experiments in nitrogen with nitrous oxide admixtures, both a purely filamentary mode and a diffuse Townsend-like discharge were generated. The addition of the electronegative nitrous oxide leads to a decrease in the energy transferred into the filaments but an increase in the breakdown voltage and the amplitude of the current pulses. Coupled with simulations it was shown that at nitrous oxide concentrations of about 1.000 ppm, the transition from an electropositive to an electronegative plasma (in which negative ions dominate) occurs.



Morphology and spatio-temporal development of a single filament in a barrier discharge in a nitrogen-nitrous oxide mixture (Höft et al., J. Phys D: Appl. Phys 53 (2019) 025203).

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Overview

The investigation of thermal plasmas is the main field of activity of the research programme "Welding and Switching".

Thermal plasmas play an essential role in technological applications in joining, cutting, and coating processes in metal processing. The research programme focuses on arc welding processes such as tungsten and metal inert gas welding as well as submerged arc welding. Work is also being carried out on laser-assisted arc welding and laser welding as well as increasingly on plasma gasification of materials that are difficult to recycle.
In electrical engineering, thermal plasmas occur in the form of the so-called switching arcs, which are ignited in switches when electrical devices are switched on or off. The focus is on the characterisation of this predominantly transient arc type in interaction with adjacent materials (electrodes, walls) in low and high voltage systems. Discharge and arcing phenomena caused by strong electric fields and insulation faults, which affect the normal operation of electrical systems and equipment and reduce their service life and functionality, are also investigated.

Because of the complex arc character and the dynamic interaction with its environment, closed models of thermal plasmas are still inadequate. Especially for the adjacent arcing areas, the materials involved and the surrounding gases often determine the scope and application possibilities of the research results. Because of the continuous development of novel components and electrically powered devices, changing fields of application, and increasingly environmental restrictions, both continuous research on the electric arc itself and the technological adaptation to the respective boundary conditions are essential.

The scientific approach combines the various diagnostic methods of an experimental (electrical, optical, and mechanical) and materials science nature with mathematical modelling and simulation. This is the only way to determine space- and time-dependent plasma parameters, such as temperature, composition, gas dynamics, and kinematic behaviour.

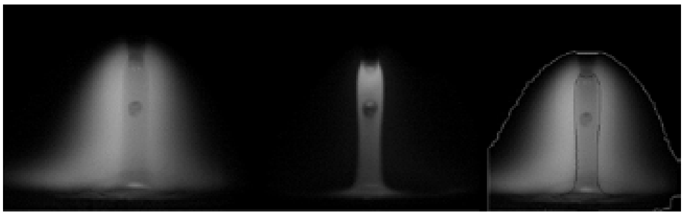
Especially in the field of optical plasma diagnostics, the INP has unique expertise. The research programme is on both optical emission and absorption spectroscopy as well as their combination with high-speed photography and high-speed two-colour pyrometry. A significant increase in competence was achieved by the adaptation of absorption spectroscopic methods for the investigation of areas adjacent to the arc.

For modelling and simulation, both classical magneto-hydrodynamic models (Navier-Stokes and electromagnetic equations) and, increasingly, non-equilibrium models are being developed without making assumptions of local thermodynamic equilibrium. This results in a much better accuracy in the description of the plasma processes occurring in the electrode regions as well as of the interaction between plasma and solid state. Furthermore, work on radiation transport and material data – also for non-equilibrium plasmas – is in focus.

The research methodology described and resulting findings can be used to optimise and further develop technological applications as well as switchgear and insulation systems. This will enable the research programme to provide approaches to meet the current objectives of volume reduction, material savings, and resource efficiency while maintaining the necessary safety, reliability, lifetime, and electrical breaking capacity.

Team of the research programme (2017–2019)

Third-party funded project: Study of the current path in gas metal arc welding for the generation of a dynamic, phenomenological system model

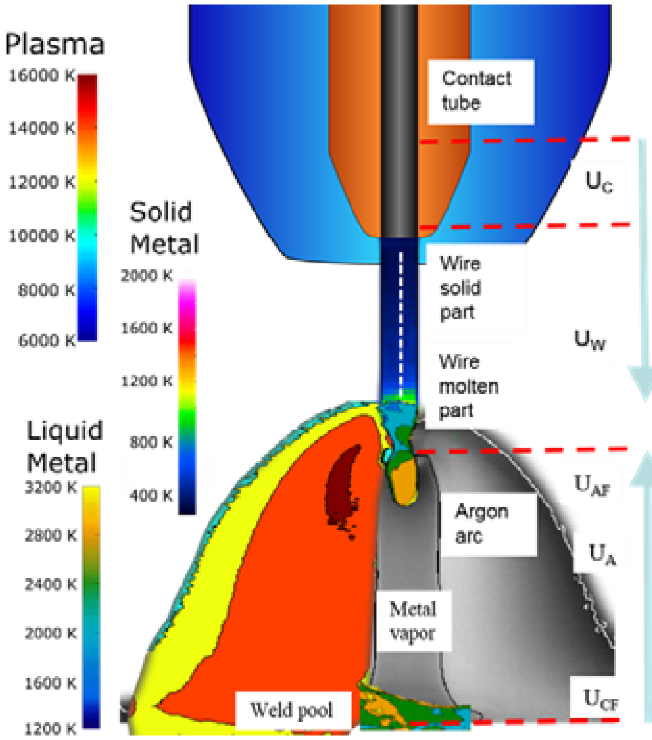


Synchronous recording of the arc (left image) with filters in the area of argon lines (left) and in the area of iron lines (right) as well as example of an image analysis (right image).

Maintaining the arc length during gas metal arc welding (GMAW) is an important prerequisite for control concepts in welding power sources to adjust stable welding processes. At present, the arc length is determined using assumptions and statistical information from the current-voltage characteristics. Here the arc length is equated to the arc column length and considered as a one-dimensional geometric variable. The deficits of such assumptions consist in the fact that, in particular, the sheath regions are significantly responsible for the energy input and thus for additional voltage fluctuations. The aim of the research proposal was therefore to experimentally analyse the active path of the contact tube – wire – drop – arc (including the sheath regions) – work piece. The areas of the active path should be considered separately by using specific diagnostics as well as by determining and utilising the different time scales of the underlying physical processes. In particular, the analysis of the total active path using time series of electrical signals and measurements of the complex impedance are coupled. The optical and spectroscopic investigation of the arc and the probing of the droplet depot are also planned.

The voltages along the active process path as a function of current and arc or free wire length for a pulsed and a spray arc process are a central result of the project. These were each determined for fixed welding and wire feed speeds and form the basis for an electrical model of the process line. For example, an increase of the sheath voltage in pulsed operation from 18 to 23 V was obtained as the pulsed current increased from 350 to 650 A while the average electric field strength in the arc was almost constant at 1.1 V/mm. The sheath voltage results in more than 60% of the total energy turnover along the effective process path. Wire and arc column contribute less than 20% depending on their lengths.

As a technologically usable result of these fundamental investigations, a description of this active path is available in the form of a process model. This model shows the behaviour of the subsystems dynamically and interdependently. In contrast to the previous approach, the results of such a phenomenological system description provide the basis for a significant improvement in arc length control in GMAW. At the same time, the prerequisites are created for further work on the physical modelling of the arcing and sheath regions on melting electrodes under the influence of metal evaporation.

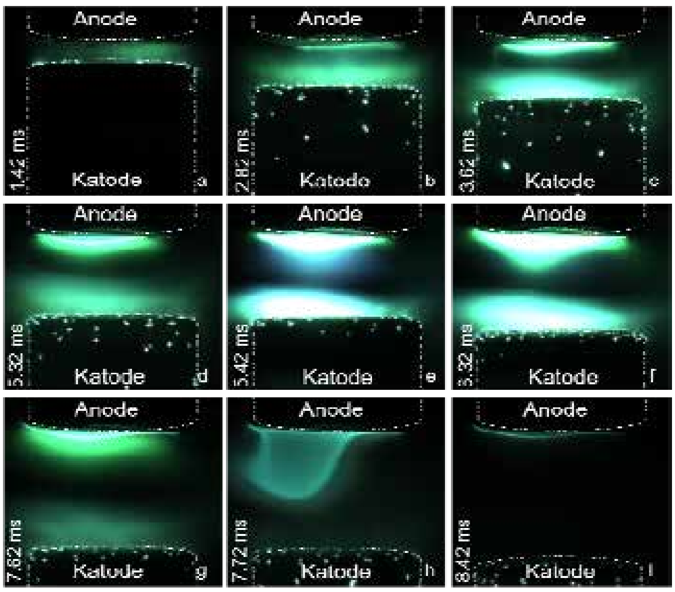


Parts of the active process path in the GMAW process with their temperature distributions in the wire and in the plasma for the example of a pulsed process during the pulse phase at 500 A

Core-funded project "Fundamentals of arc plasma"

A significant improvement in the switching capacity and reliability of arc-based switchgears requires detailed knowledge of the properties and dynamics of the resulting arc plasma. Special attention must be paid to the regions adjacent to the plasma, like e.g. electrodes and housing walls. The focus of the core-funded arc project is the interaction between plasma and the surrounding medium (air, gas, vacuum). This is investigated using optical diagnostics with high spatial and temporal resolution in combination with numerical models.

Extensive work in the core-funded project was carried out in particular to analyse arcing at the anode under vacuum conditions. For this purpose, a set-up was used to simulate the processes in a medium voltage vacuum circuit breaker. This consists of a 52 l vacuum chamber with optical access in which both specially prepared and real contact systems can be attached. Using high-speed photography and spectroscopy, different physical phenomena of the switching arc are investigated. For example, anode phenomena for vacuum arcs at large current amplitudes show a strong dependence on the current and contact opening. Because concentrated foot points increase electrode erosion or metal vapour formation, this phenomenon is decisive for the re-solidification of the contact gap after current zero crossing. A successful current interruption can occur only if no further ionisation of the metal vapour in the electrode chamber can take place when the recurring mains voltage or the transient overshoot voltage impinges.



High-speed recordings of the different appearance modes of the arc foot point in vacuum: Diffuse mode (a and i), foot point (b), anode spot type 1 (c and d), anode spot type 2 (e, f and g), Anode plume (h) Diffuse mode during current decay (i). The current-related recording time (50 Hz sinus) of the different modes of appearance is shown in the image

In view of the rapid adaptation of vacuum switching technology from medium voltage (up to approx. 72 kV) to high voltage (up to 145 kV) applications and above, the experimental possibilities of the research programme were extended by the development and construction of a new high current generator "Caesar" as well as a transient overshoot voltage generator "Dora". This makes it possible to investigate the switching behaviour of new and conventional switchgear and contact systems of higher power under load with sinusoidal 50 Hz currents of up to 80 kA effective (peak value approx. 120 kA). It will also be possible to test the re-solidification behaviour of the switching path around current zero with transient over-voltages of up to 45 kV and 1 kHz.

The newly constructed "Dora" overshoot voltage generator (left) and "Caesar" high-current generator (right) in the Institute's arc laboratory

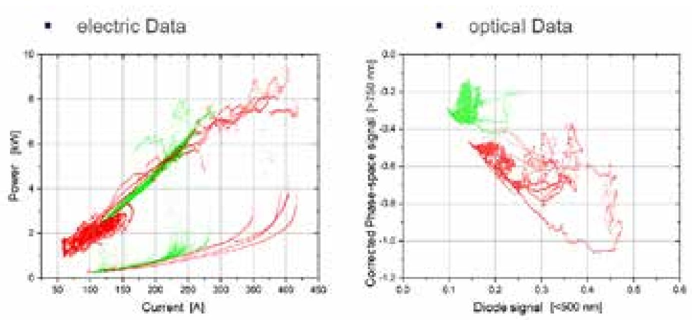
Third-party funded project: "Use of optical sensor technology for the characterisation of emissions and process stability in gas metal arc welding"

The aim of the project was to create an easy-to-use tool for controlling and reducing emissions as well as for monitoring process stability in gas metal arc welding (GMAW). Using low-cost sensor units based on photodiodes of different spectral sensitivity, the emission of UV radiation and the generation of welding smoke in the arc process can be measured without a connection to the welding machine. If the user roughly specifies the process type and the basic and additional material, the evaluation unit compares the measurement results with threshold values and indicates times or seam positions of particular deviations in emissions and process stability.

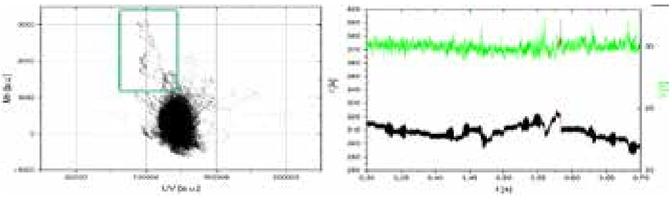
The solution approach consisted of the systematic investigation of correlations between emissions, process stability, and arc radiation of different GMAW processes. The subsequent modelling includes cross-process characteristics, process-specific emission mechanisms and correlations with temporary deviations such as short circuits, spatter formation, and delayed drop separation.

In manual welding, for example, the tool can enable more precise control of emission levels, thus providing the user with information for a more targeted design of occupational safety and working conditions. The tool can promote the use of emission-reduced processes and also serves as a control tool for process stability, thus reducing the effort involved in optimising welding processes.

The analysis of the welding processes carried out by means of optical sensors within the framework of this project in the research programme points out that the intelligent processing of the measurement data in real time allows the detection of relevant events, which cannot be communicated with the purely electrical data (see picture).



Red: faulty process part, green: non-faulty process part.
During a welding test, both the standard electrical data and the optical data were recorded using our spectral selective sensor. With the help of the sensor, the good process section can be easily separated from the bad.



Green rectangle: Increased manganese output during a welding process. The same time is marked on the right side of the electrical signals. This deviation can be clearly detected only in the sensor signal.

Furthermore, harmful emissions of manganese (for example) in the welding smoke are also detected. This makes it possible to monitor workplaces and thus ensure the safety of the welders. This was not possible by purely electrical measurement.

In the long term, the tool can also be used to introduce new processes and monitor compliance with standards on emissions.

Completed sensor board equipped with 2 diodes. The compact size already achieved in the prototype allows easy installation in a safety helmet and can enable a much more compact size for mass production without the BNC measurement connections.

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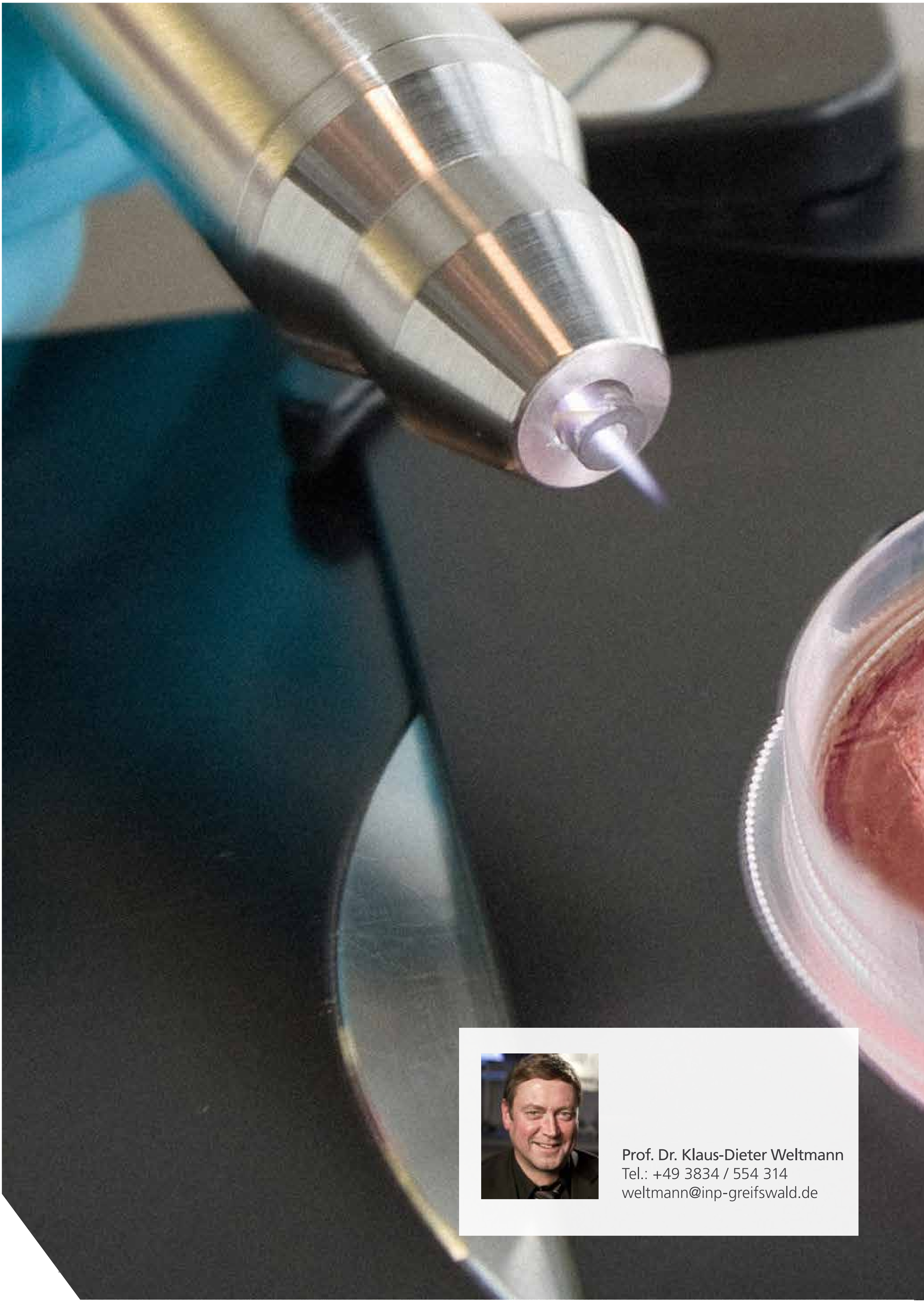

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RESEARCH DIVISION

ENVIRONMENT & HEALTH

Overview

The research division Plasmas for Environment and Health uses the synergies of its three interdisciplinary research programmes Bioactive Surfaces, Plasma Medicine, and Decontamination. Atmospheric pressure plasma sources are an essential link in this regard. For example, dielectric barrier discharges as well as jet plasmas, microwave plasmas, and microplasmas are extensively investigated. The close cooperation of physicists, biologists, chemists, pharmacists, physicians, and engineers with highly specialised technicians and laboratory specialists is unique worldwide.

In plasma medicine, the focus is on fundamental research of interactions of physical plasmas with living cells and tissues. The research and introduction of new plasma-based methods in medicine is also being promoted. In the field of bioactive surfaces, customised surfaces for life science applications are being investigated. Another focus is plasma-based decontamination: Among other things, the focus here is on exhaust air purification and the disinfection of food and water as well as the treatment of agricultural goods.

Research programme bioactive surfaces

- ÖkoClean – Ecological and functionally optimised pretreatment chain for the plasma coating of complex shaped cutting tools
- Growth core MikroLas – surfaces shaped by photonics

Research programme plasma medicine

- Plasma and cell – plasma-based processes in medicine
- Centre for Innovation Competence (ZIK) "plasmatis – plasma plus cell"

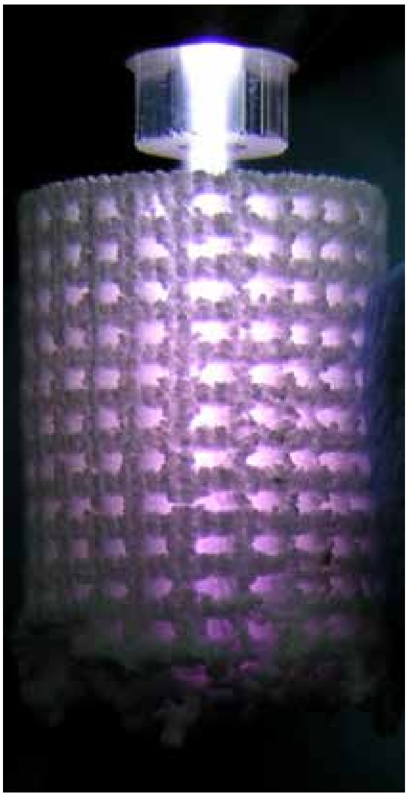
Research programme decontamination

- Discharge processes in aqueous solutions
- Disintegration of biomass by combining plasma and ultrasonic treatment

Overview

For applications in the life science sector (e.g. hygiene, medicine or biotechnology), a surface modification of the products is necessary to create specific properties. Depending on the modification process used, the wetting properties of surfaces can be controlled so that they are more hydrophilic or hydrophobic. Certain chemical functions can also be generated on the surface in order to improve biological compatibility. Plasma-based processes in particular make it possible to chemically and morphologically modify a wide range and variety of surfaces in such a way that the range of applications is considerably expanded. In order to improve the interfacial compatibility of biomaterials and to initiate specific reactions of the biosystem in contact with the surface, they are functionalised using low-temperature plasmas. Virtually independent of substrate geometry and material, plasma coating generates new, specific properties for biomedical and biotechnological applications.

Because the process costs and the simple integration of plasma processes into existing production lines are particularly important, especially in industrial applications, the INP offers processes at low pressure (for the highest purity) as well as at atmospheric pressure (for short process times).



Fields of application

Antimicrobial surfaces

Antimicrobial surfaces mainly serve to prevent infection. In particular, implants, tweezers, scalpels, or other medical devices that come into direct contact with the patient require particular attention. In order to prevent the colonisation of surfaces with pathogenic bacteria, various plasma-based techniques are used to produce photocatalytically active surface modifications based on titanium dioxide (which have antibacterial and self-cleaning properties when irradiated with UV light) or antimicrobial films (the bactericidal effect of which is based on metallic compounds such as copper or silver). In order to create the longest possible antimicrobial effect, metallic particles can be embedded in a polymer or glass-like matrix. For example, the release behaviour of the antimicrobial additives is controlled.

Cell-adherent surfaces

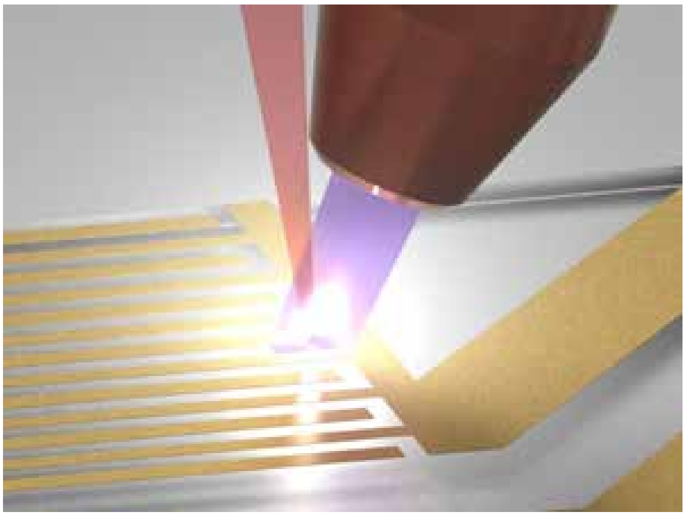
Plasma processes are particularly suitable for equipping surfaces with reactive chemical groups such as amino and carboxyl groups, which significantly improve cell response, especially cell density, cell distribution, adhesion, proliferation, and differentiation. Furthermore, the binding of biomolecules is possible by different immobilization strategies such as the covalent coupling of linkers and spacers.

Anti-adhesive surfaces

Anti-adhesive surface properties are of particular advantage for transient implants such as fixators or temporary screw connections. Furthermore, such surfaces are easy to clean because dirt and oils/greases as well as organic material hardly adhere to them. With the help of plasma technology, such surfaces can be applied quickly and economically.

Application-oriented outlook – hybrid processes

Laser-plasma processes



Economic success in medical technology, diagnostics, and sensor technology requires the continuous research and development of innovative products and manufacturing processes. As a rule, these are subject to the highest requirements for precision, quality, and reproducibility. They must also cover a wide range of different materials. In the course of advancing miniaturisation and increasing functional integration, product and component surfaces must also take on special functions in order to acquire medically or biologically advantageous properties.

The combination of innovative technologies enables ultra-precision machining, which is particularly crucial for industrial production. Laser-plasma hybrid processes can be used for both coatings and high-precision ablation. They can be applied as either local or surface process variants. This allows materials to be functionalised using atmospheric-pressure plasmas and, in combination with laser pulses, coated or structured with specific lateral dimensions down to the micrometre range.

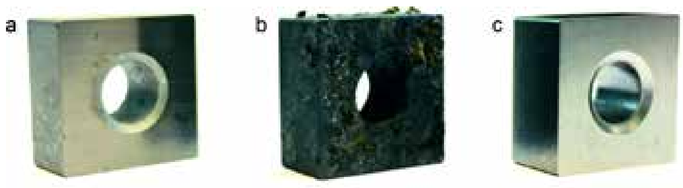
Core-funded project ÖkoClean – Ecological and functionally optimised pretreatment chain for the plasma coating of complex shaped cutting tools

High-performance tools for milling, turning, or drilling play a key role in various areas of industrial production. For their application, the surface quality in particular is decisive for function and durability. In order to maximise the service life of a tool, wear protection or hard material films are applied, among other things. Before coating, however, impurities that arise during the manufacturing process must be thoroughly removed. This is because high surface quality is essential for sufficient adhesion between the tool surface and coating.

In cooperation with other partners from the institutional and industrial environment as part of the Ökoclean project (33033/01-2), which is funded by the DBU, the INP is investigating electrolytic plasma polishing (PEP) as a cleaning process.

For the PEP, the INP uses a system that enables the treatment of components with a maximum of about 100 cm^2. In PEP, the component to be treated is immersed in an electrolyte solution, and an electric field is applied between the component and the counter electrode. The electrical conductivity of the electrolyte solution was controlled by adding material-specific salt solutions. Typical voltages > 100 V cause gas released during the process to surround the work piece with a thin gas film in which a plasma is formed. The generation of this plasma is essential for the desired surface modifications. The method offers both economic and ecological advantages over other cleaning and polishing methods because the technique is comparatively fast, simplifies the process chain and, compared with other electrochemical methods, reduces the costs for the disposal of harmful chemicals. It could be shown that with PEP cleaning, degreasing, deburring and surface finishing can be realised in a single process step within a few minutes.

In the project, PEP was used to clean high-performance carbide tools in order to achieve good adhesion values for the subsequent coating. Test specimens were subjected to a defined, reproducible surface contamination before cleaning. This is prototypical for the load of components during the production of cutting tools. By optimising the process, it has been possible to free the surface from these stubborn encrustations (see figure). Adapted process control means that the radius of the cutting edges can be adjusted in a defined manner. In a subsequent PVD process step (HIPIMS), components cleaned with PEP were provided with a TiN hard coating. Within the scope of stress-strain analyses at the project partners, the adhesive strength of these TiN films as well as other hard material coatings (AlTiSiN) produced by partners was investigated. The practical applicability of the PEP process for cleaning and conditioning before coating was thus proven. With the new, more environmentally friendly cleaning process, it was possible to achieve similarly long tool service lives as with conventional yet environmentally damaging processes.



Test specimens in the PEP process: (a) untreated, (b) contaminated, (c) cleaned and polished

Third-party funded project
Growth core MikroLas – surfaces shaped by photonics

Economic success in economic sectors such as medical and precision engineering, mechanical engineering, or sensor technology requires the continuous research and development of innovative products and manufacturing processes. These are subject to the highest requirements for precision, quality, and reproducibility. They must also cover a wide range of different materials. In the course of advancing miniaturisation and increasing functional integration, product and component surfaces must also take on special functions in order to acquire medically or biologically or technically advantageous properties. The key to success lies essentially in the optimal design of the surfaces.

The growth core "MikroLas – surfaces shaped by photonics" addresses these problems. It combines innovative technologies from various research areas of ultra-precision machining and develops them specifically for industrial production and implementation in (prototype) applications of the alliance. The developments of the disruptive technology platform are based on the combination of time-shaped ultra-short laser pulses with atmospheric pressure plasmas. While the former allow machining accuracies and structure sizes of a few 100 nm in almost athermal processing, atmospheric pressure plasmas allow the functionalisation and activation of surfaces over large areas and (in combination with ultra-short laser pulses) the targeted coating or structuring of surfaces with lateral dimensions down to the micrometer range. Starting from these basic technologies, the necessary process and system technologies as well as production processes suitable for industrial use are developed in the growth core and demonstrated on prototypical applications. The aim of the consortium is to become one of the world's leading production sites for the photonic production of functional surfaces until 2025 by developing the MikroLas technology platform.

In addition to the INP, neoplas GmbH, SITEC Industrietechnologie GmbH and S.K.M. Informatik GmbH are involved in this sub-project.

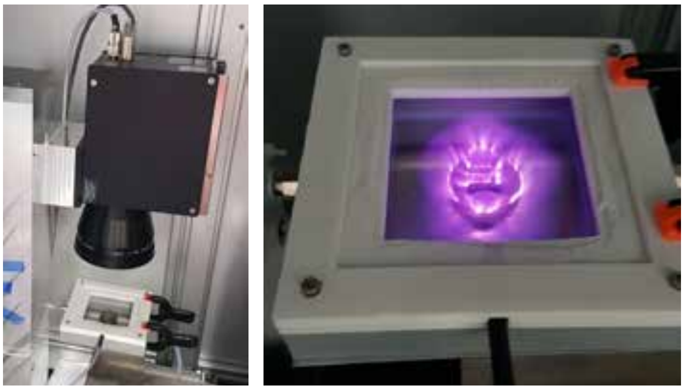
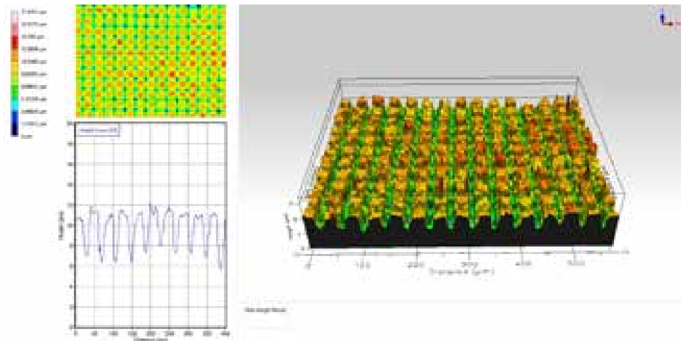


Figure 1: Left: Scanner head with a flat plasma source; right: flat plasma source with dental implants.

Figure 2: Laser structures in Ti6Al4V examined with the white light interferometer



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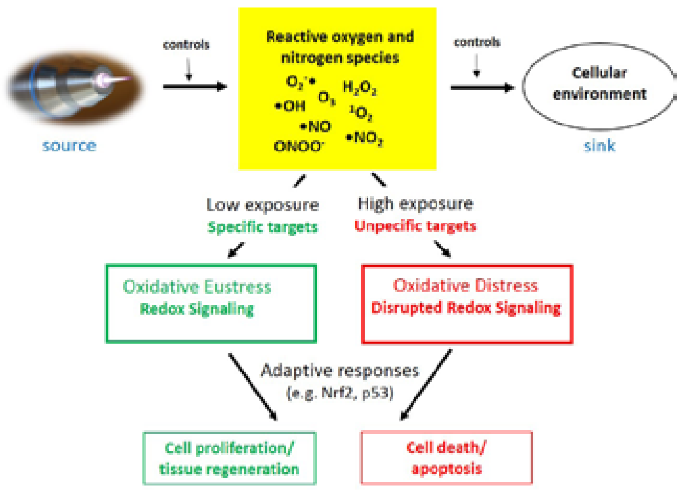
Overview

Plasma medicine is an innovative field of research at the interface between physics and the life sciences. It deals with the influence of cold atmospheric-pressure plasmas on biological processes in living cells and tissues as well as the medical use of these plasmas. In addition to the effective inactivation of micro-organisms, the stimulation of tissue regeneration and the destruction of cancer cells offer potentials for medical applications. Accordingly, the research work of the research programme Plasma Medicine is focused on the following three topics:

- the clarification of the biochemical and molecular mechanisms of biological plasma effects with special consideration of redox-based processes
- the support and monitoring of clinical research and of therapeutic application of cold atmospheric-pressure plasma sources
- the design, construction, and characterisation of experimental plasma sources for biomedical applications



Plasma medicine as applied redox biology: Depending on the plasma parameters and the biological environment, redox-controlled processes are activated. These can lead to the stimulation or inactivation of cells

For this research work, a broad spectrum of microbiological as well as cellular and molecular biology techniques is available in modern laboratories. These are combined with the plasma physics and engineering expertise established at the INP over many years in an interdisciplinary research structure. Since 2018, the research work of the Research programme Plasma Medicine has been strengthened by expertise in the field of modelling and simulation, in order to better describe in particular plasma-liquid interactions and plasma effects on cells and tissue and thus to support and supplement the experimental work. Cooperations especially with the University Medical Centre of Greifswald and the University Medical Centre of Rostock guarantee the close relation of the research work to clinical requirements and issues. The commissioning of three laboratories at the Karlsburg Diabetes Centre of Excellence of the Karlsburg Hospital in 2018 is a further important step towards application-oriented and clinically oriented plasma medical research.

The atmospheric pressure plasma jet kINPen was designed and intensively investigated at the INP and further developed into a product by neoplas tools GmbH Greifswald. It was CE-certified as kINPen® MED 2013 as a Class IIa medical device and is used in particular for the treatment of chronic wounds. It forms an essential basis of application-oriented research expertise in the field of medical plasma devices. Through the ever better characterisation and control of the physical properties of cold atmospheric pressure plasmas in interaction with living systems, plasma devices are being redesigned and optimised in order to improve medical applications and open up new fields of application. Cooperation with industrial partners ensures the transfer of research results from the laboratory to the development of plasma devices for clinical applications. This includes consulting services on the use of plasma technologies in medicine.

The use of cold atmospheric-pressure plasmas in medicine, particularly in the treatment of wound healing disorders and pathogen-related skin diseases, is now increasingly finding its way into clinical practice. Research in plasma medicine to elucidate the molecular mechanisms of plasma-stimulated wound healing as well as the application safety of cold atmospheric pressure plasma sources have contributed to this development.

Application-oriented outlook

PLASMA SOURCES FOR MEDICAL APPLICATIONS

The use of cold atmospheric pressure plasmas in medical therapy has become clinical reality. As a result, the number of commercial suppliers of plasma equipment for medical and, increasingly, cosmetic applications is also increasing. Assessing atmospheric pressure plasma sources with regard to their suitability for medical applications requires uniform criteria before clinical investigations are carried out. In addition to the general regulatory requirements for medical devices, which of course also apply to medical plasma devices, standards that sufficiently take into account the special effect and application properties of cold atmospheric pressure plasma sources must be developed. The DIN specification (DIN SPEC) 91315 “General requirements for medical plasma sources”, which was published in 2014, will be developed in cooperation with the National Centre for Plasma Medicine e.V. (NZPM) to become a regular DIN standard by 2021. In parallel, semi-automated processes for the DIN-compliant characterisation of plasma sources are established in the research programme Plasma Medicine and offered for industrial cooperations.

In the field of redesigning plasma devices, the research activities focus on flat plasma sources. On the one hand, these are based on the established technology of the atmospheric-pressure plasma jet kINPen. On the other hand, they increasingly focus on other principles of plasma generation, especially via dielectric barrier discharges. Fundamental requirements for medical devices are included in the source concepts from the outset.

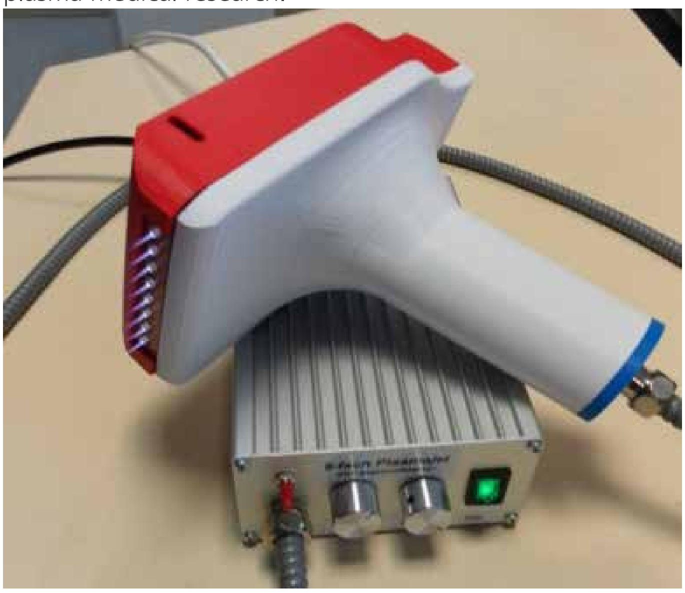
WOUND HEALING AND CANCER TREATMENT

The plasma effects for the stimulation of tissue regeneration (which have meanwhile been comprehensively described) as well as for the inactivation of cancer cells are based mainly on the influence of redox-based cellular processes. The expertise acquired in the field of redox biology in the programme Plasma Medicine will also be effective in clarifying such mechanisms in other pathological processes, thus extending the research spectrum beyond plasma medicine.

In the field of wound healing, the focus is on further research into specific aspects of plasma efficacy in diseases such as diabetes mellitus. In addition, the support of clinical studies, the evaluation of clinical applications, and the conclusions drawn for the optimisation of plasma medicine applications will increasingly become part of the research programme Plasma Medicine. With regard to application in cancer therapy, the conditions for the use of plasma in clinical settings, aspects of application safety, and the possibility of combining plasma with other therapeutic options must be clarified in detail.

PLASMA THERAPY SYSTEMS

The combination of medical plasma sources with imaging techniques for the real-time analysis of treated biological targets (e.g. wound surfaces) as well as with plasma diagnostics to monitor plasma parameters during treatment will lead to a new generation of plasma therapy systems that may even be feedback-controlled and automated. To this end, the modelling of complex interactions between plasma and living tissue as well as the incorporation of artificial intelligence techniques must be integrated into plasma medical research.



Laboratory sample of a plasma jet array for medical application based on the kINPen MED® for the treatment of larger areas

Core-funded project "Plasma and cell"

The work in the core-funded project "Plasma and cell" project complements the research work of the third-party funded ZIK plasmatis under the umbrella of the research programme Plasma Medicine.

WOUND HEALING – ANIMAL MODELS

As a result of animal studies, the molecular mechanisms of plasma wound healing were further decoded on the basis of comprehensively evaluated blood and tissue samples. The molecule Nrf2, which is important for cellular redox homoeostasis, and the protein p53, which is decisive in regulating the cell cycle, were identified as key cellular factors.

WOUND HEALING – CLINICAL RESEARCH

Within the framework of the consolidated ZIK research group "Plasma Wound Healing" at the KDK, a hyperspectral camera system is used to visualise therapeutic plasma effects, especially in the treatment of diabetic wounds. Supplemented by the analysis of wound exudates, it was thus possible to further advance clinical research in order to optimise plasma-assisted wound healing.

CANCER TREATMENT – CLINICAL RESEARCH

In cooperation with the University Medical Centre of Greifswald, the plasma effectiveness against cancer cells was examined on 3D cell culture models (spheroids) and tissue biopsies, in particular to identify possible differences between healthy and cancer cells. In addition, initial therapy trials for the treatment of precanceroses in the oral cavity were accompanied by tissue and saliva tests. The comprehensive histological and histochemical examination techniques available at INP form the basis for cooperation with clinical partners.

PIGMENTATION DISORDERS OF THE SKIN

The possible use of cold atmospheric-pressure plasma to influence skin pigmentation is being investigated as part of a doctoral thesis. The initial results with melanoma cells suggest that it is basically possible to stimulate melanin synthesis by means of plasma exposure.

PLASMA-TREATED LIQUIDS

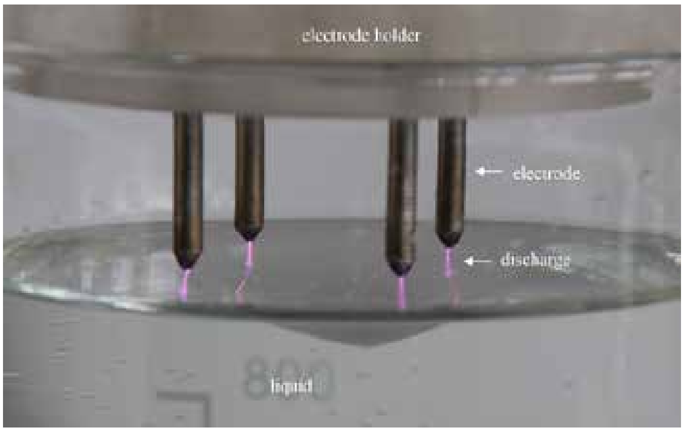
The use of antimicrobially effective plasma-treated liquids as disinfectants or antiseptics requires the plasma treatment of larger volumes of liquid. A plasma source based on a pin-to-liquid discharge was developed and extensively tested for this purpose. It was also shown that in the presence of proteins, the antimicrobial efficacy of plasma-treated saline solution is dramatically reduced.

MODELLING/SIMULATION

Since 2018, the field of modelling/simulation of plasma sources in interaction with biologically relevant targets has been integrated into the research structure of the research programme Plasma Medicine. A first model to study the complex transport phenomena of reactive species from the effluent of a plasma jet into a liquid volume has been developed.

PLASMA AGRICULTURE

The expertise available in the "Plasma and cell" project as well as in the ZIK plasmatis on cellular and biochemical mechanisms of biological plasma effects with the aim of medical application of cold atmospheric-pressure plasma was used to contribute to the new research field "Plasma Agriculture" established at the INP. This allowed research in this novel field to be built on a solid scientific foundation.



wINPlas: pin-to-liquid discharge for the plasma treatment of larger volumes of liquid

Third-party funded project: Centre for Innovation Competence (ZIK) "plasmatis – plasma plus cell"

After a successful initial funding period (2009–2015) of the ZIK plasmatis by the BMBF, the junior research groups "Plasma Redox Effects" and "Plasma Liquid Effects" started their work in 2016 and 2017 within a second five-year funding period. The two junior research groups of the first funding phase were consolidated as research groups "Plasma source concepts" and "Plasma wound healing" at the INP. As part of the basic research project "Plasma and cell", these form the interface between ZIK plasmatis and the other research activities of FS plasma medicine.

The work of the Junior Research Group "Plasma Redox Effects" focuses on research into the cell- and molecular-biological possibilities of a redox-based anti-tumour strategy and immunotherapy using cold plasma in order to open up new options in cancer therapy. In cooperation with the core-funded project "Plasma and cell", this junior research group investigates the fundamentals of redox-based cellular processes and their influence by cold atmospheric-pressure plasma. Since 2018, the junior research group has been involved in the project "ONKOTHER-H: development platform for innovative oncological therapies using the example of the most common human cancer – skin cancer", which is funded by the Excellence Initiative of Mecklenburg-Western Pomerania.

The Junior Research Group "Plasma Redox Effects" systematically investigates the path of reactive species from plasma to liquid phases to biological target structures. By analysing the change in specific biochemical targets as a result of plasma treatment with varying plasma parameters, not only cellular biological and biochemical reaction cascades. but also plasma effects on the basis of chemical or biological efficacy parameters will be clarified, thereby addressing the problem of a "dose" definition for biological plasma effects.

Research structure of the research programme Plasma Medicine: Combination of the ZIK plasmatis with other topics of the core-funded project "Plasma and cell"

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Overview

The research programme is primarily concerned with the investigation, development, and optimisation of plasma-based methods and processes for the degradation of pollutants and micro-organisms in air, water, and on surfaces, including food products. These activities are motivated in particular by the United Nations' goals for sustainable development. The aim of the research programme is to make a significant contribution to the topics of "Water and the improvement of hygiene" and "Food security and sustainable agriculture" as well as "Environment" and "Management of natural resources", respectively.

This demand is reflected in the development of the current fields of work and fields of application. In addition to reducing anthropogenic contamination, especially in surface waters, the fight against the spread of drug-resistant germs has also come to the forefront. In addition, the potential of plasma methods has now also established itself for applications in agriculture and agricultural production and now forms a special Research programme.

Plasmas can make an important contribution to various sustainability goals set by the United Nations. This includes, in particular, methods for conserving water resources, measures to prevent the spread of diseases, and contributions to sustainable agriculture.

The mechanisms of action provided by a plasma for various applications and tasks are chemically reactive species, ultraviolet radiation, and electric fields as well as shock waves in liquids. By providing energy and operating parameters in a suitable manner, these processes can be specifically controlled. All approaches have in common that they allow treatment with a relatively small increase in temperature and are therefore particularly suitable for application on temperature-sensitive goods such as plant material. Furthermore, especially for plasmas generated from ambient air or water, no long-lasting harmful reaction products are to be expected.

Fields of application

Clean air

The research topic has traditionally been dedicated to the development of new processes for the degradation of pollutants in gas flows and ambient air. The combination with an ion wind in particular can efficiently degrade germs in the ambient air (e.g. in hospitals). This approach is now also being investigated for the treatment of indoor air in livestock stables.

Clean water

In the past, the research topic has dealt mainly with the degradation of pharmaceutical residues in drinking and waste water. Corresponding approaches to reduce herbicides and pesticides are now being investigated. The successful degradation of antibiotic-resistant bacteria in water has also been demonstrated.

Clean food

This research topic investigates direct and indirect plasma treatments for the food industry. The aim is to keep transport routes and packaging microbially clean and to gently preserve fruit and vegetables longer after harvest.

Clean healthcare

This research topic focuses on the plasma-based biological decontamination of sensitive medical devices as well as on cost-effective solutions for cleaning consumer products (e.g. contact lenses). Room disinfection in care facilities has also become more important. Here, room air treatment is considered in addition to surface treatment.

Application-oriented outlook

Non-thermal plasmas for agriculture and agricultural production

The germ contamination of various agricultural products, especially fruits and vegetables but also seeds, can be effectively and efficiently reduced by plasma processes. This has been confirmed in various studies on a variety of micro-organisms. On the one hand, this can increase consumer safety and confidence in consumption. On the other hand, it increases shelf life and storability for trade and logistics. There are three approaches for an economic treatment. In the case of direct treatment, the product is actually exposed to a plasma. This contrasts with indirect treatment methods in which the air processed by a plasma is used either to fumigate food or is introduced into water, which thereby becomes antimicrobially effective and can be used effectively for washing. Both methods are based on the generation of reactive species that degrade in a relatively short time.

The concentration and effectiveness can be controlled by the process, thereby allowing the plasma to be used as efficiently as possible. In addition to a series of fundamental investigations, two indirect processes for industrial applications have been scaled up. The focus was on technical aspects of process engineering as well as plant safety and reliability for the treatment of larger quantities of goods in relevant production environments. Accordingly, production-related demonstrators (e.g. for the treatment of broccoli with plasma-processed air and the cleaning of lettuce with plasma-treated water) were successfully designed and tested. Because of the greater proximity to commercial use, investigations on the influence of the various plasma processes on product quality were also intensified.

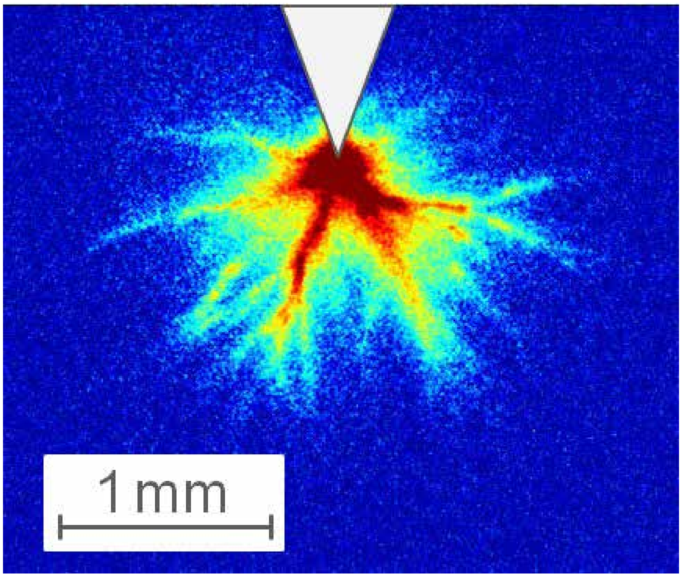
Treatment of sunflower seeds by corona discharge. The treatment kills micro-organisms on the surface of the grains. In addition, their ability to absorb water increases, and metabolic processes are stimulated.

In addition to using plasma to decontaminate the final product, it can also effectively remove pathogens from seeds, thus promoting germination and the health of the seedling. Accordingly, plasma applications could represent an alternative to conventional seed pre-treatment processes (e.g. seed dressing). This also increases the water absorption capacity of the grains. Metabolic processes (i.e. germination and growth) are also promoted by reactive oxygen and nitrogen species. In particular, irrigation with plasma-treated water also appears to be a way of adding additional nitrogen to the plant and effectively controlling plant pests. As a result, early growth processes in particular can be supported, and crop yields can ultimately be increased. Under certain circumstances, plasma-treated water itself could also offer a more environmentally friendly alternative to pesticides and insecticides. Overall, a better understanding of the relevant processes ultimately suggests various possibilities for replacing or at least supplementing the widely criticised use of agrochemicals.

Core-funded project
Discharge processes in aqueous solutions

The efforts of the research programme are characterised by the development of various plasma processes and technologies for decontamination in various fields of application. In recent years, the interaction of plasmas with water and generally aqueous solutions has been the main focus. Now that degradation pathways and inactivation mechanisms have been identified for various applications, the main question is how mechanisms of action depend on plasma parameters (i.e. on the original physical processes and the operating parameters of a plasma method).

For many applications the chemically reactive species formed are decisive. Basic investigations deal with how these are determined by the structure and course of the discharge. To this end, for example, pulsed corona discharges in water (which have already been described for the degradation of pharmaceutical residues) were investigated in detail. In a defined geometry, the discharge structure was characterised as a function of pulse duration and pulse voltage, as well as of the conductance of the water was characterised with a time resolution of only a few nanoseconds. It has been shown that, in addition to the pulse rise time, the development of the discharge during the drop of the applied voltage can greatly influence the reactive species formed in this afterglow phase. This is also made clear by the re-illumination processes observed for this phase. Furthermore, it became clear that longer high-voltage pulses are not necessarily more efficient in generating reactive species. The studies are supplemented by a detailed description of the reaction kinetics of the chemical components originally provided by the plasma. Especially for the inactivation of micro–organisms, great importance is attached to the peroxinitrite formed from them. However, under certain circumstances, this substance can decompose again quite rapidly without becoming effective. The formation and degradation were therefore determined by time-resolved *in situ* UV spectroscopy. Formation rates and residence times of peroxinitrite depend strongly on the buffer capacity of the aqueous solution and ultimately determine the antimicrobial effectiveness.



Reillumination (3 ns recording time) of a corona discharge ignited in water on the 20 ns falling edge of an applied high voltage pulse of 100 ns (FWHM) and 50 kV amplitude. For rapid decay, all channels of the original discharge light up again and suggest an appropriate current distribution.

In addition to corona discharges, which are generated directly in the water, spark discharges, which are also only generated with short high-voltage pulses, have proven to be an efficient method for the disintegration of plant cells and especially algae. Corresponding fundamental investigations have shown that this method is superior to other methods, especially for extracting temperature-sensitive ingredients. The mechanism of action is based on the generation of strong shock waves. The pressures of these clearly exceed the load limit of the cell wall as proven by corresponding measurements. In contrast to corona discharges in water, the reaction chemistry plays only a minor role and has no harmful influence on the substances extracted.

The results of all these fundamental studies have now been used to design improved plasma treatment systems – either for the degradation of pollutants and micro-organisms or the launch of new application projects.

Third-party funded project disintegration of biomass by combining plasma and ultrasonic treatment

With the disintegration of biomass, the expertise of the research programme has been extended by a further field of activity. By combining ultrasonic treatments with a plasma, the energy yield in biogas plants should be significantly increased and environmental pollution reduced. Biogas plants are currently reaching their limits because many of the processed substrates, especially liquid manure or straw, still contain numerous organic components that are insufficiently disintegrated and therefore not accessible to fermentation. In some cases, only up to 65% of the hardly degradable organic components can be processed by the bacteria. Ultrasound already offers a possibility to improve the disintegration – but also only incompletely. The ultrasonic treatment in a common reaction chamber will therefore be further improved by simultaneous treatment with a plasma. Overall, this is expected to yield more than 90%. The plasma is used to attack the plant cells not only mechanically but also chemically.

For the project, which is funded by the Ministry of Economics, Employment and Health of the State of Mecklenburg-Western Pomerania and managed by the planning office Power Recycling Energy service (PRE) from Neubrandenburg, the research programme Decontamination develops and investigates various plasma processes. Initially, large-volume spark discharges were considered as well as plasmas generated directly in the biomass suspension by microwave excitation. The latter offer the possibility of coupling comparable power in the range of kilowatts to ultrasonic treatment. Investigations on a cellulose model have confirmed that this results in a disintegration comparable with ultrasound and significantly better in combination with it. The contribution of the plasma can be attributed to chemical reactions. In these processes, nitrogen in particular can be bound. This means that environmentally harmful compounds such as ammonia in the fermentation residues that later end up on the field can be reduced.

Before the approach will be tested with a demonstration model in the biogas plant in 2020, preparatory studies are currently being carried out on real biomass substrates at the University of Rostock.

In addition to the use in biogas plants, there are further possibilities in the processing of agricultural products. In addition, the combination can also represent a new way of treating waste water that is highly contaminated with germs or pollutants.

Biogas plant in Bentzin (District of Vorpommern-Greifswald). The plant will use a combination of ultrasonic and plasma treatment to increase the disintegration of processed biomass substrates and thus ultimately the biogas yield.

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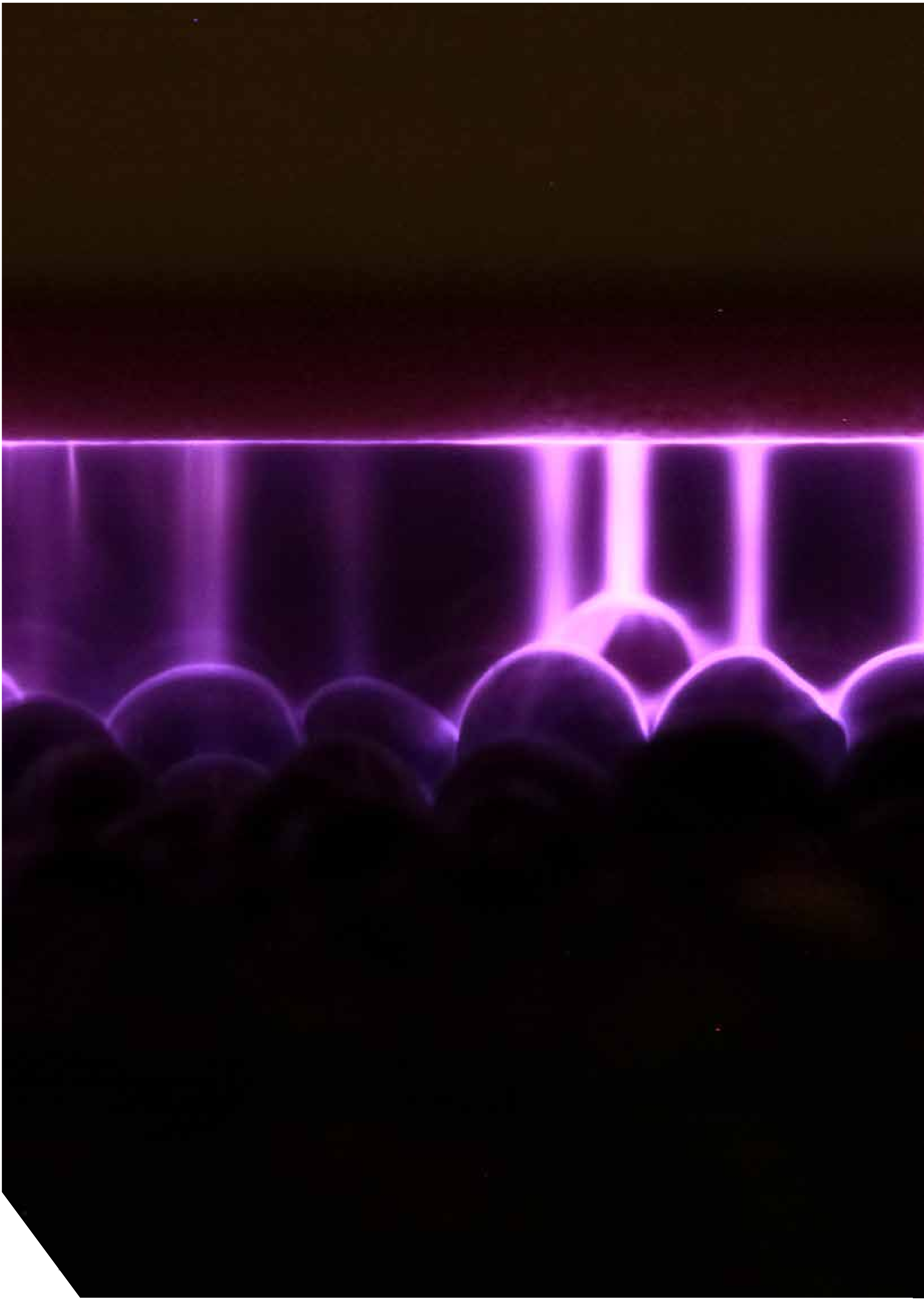

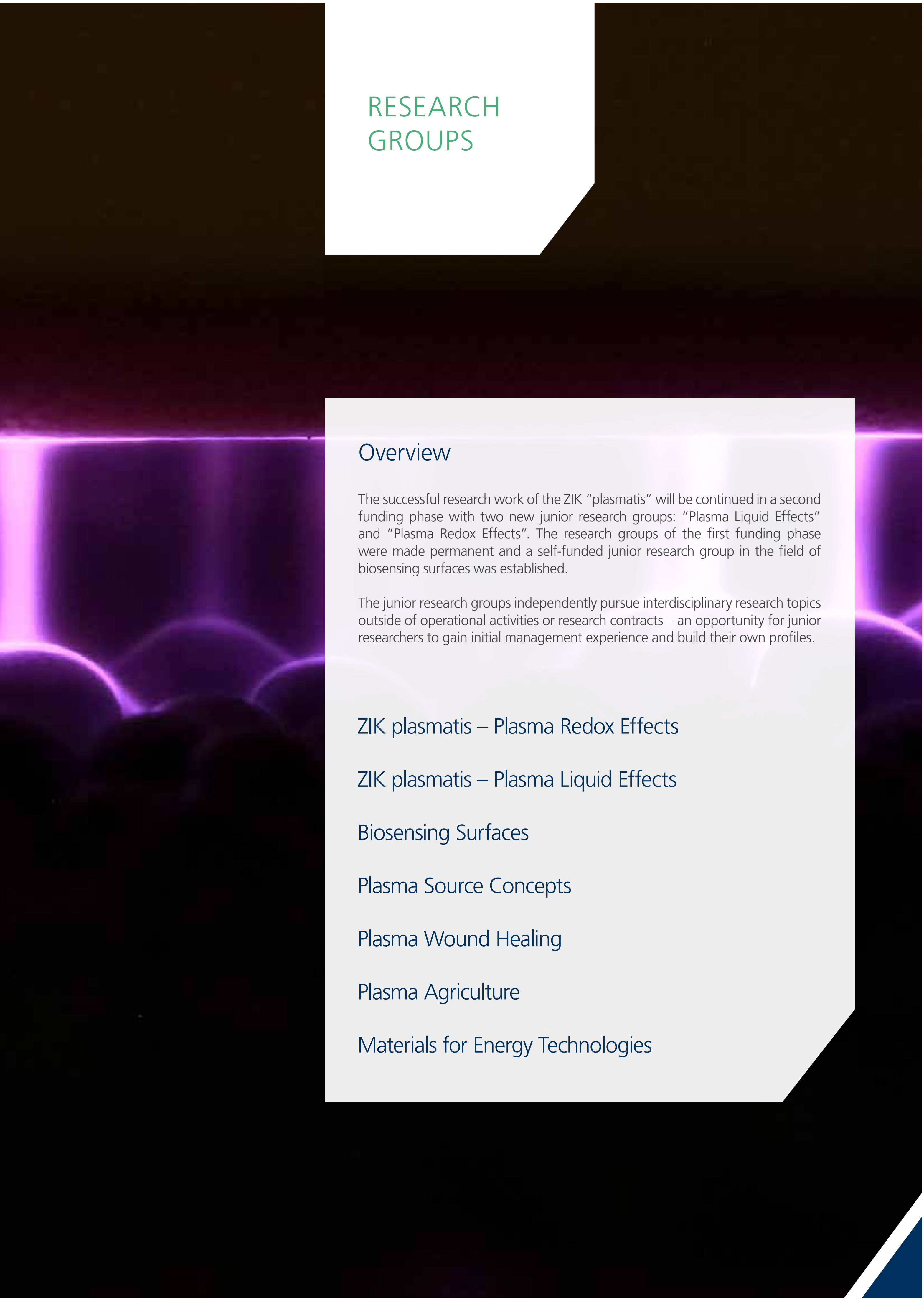

RESEARCH GROUPS

Overview

The successful research work of the ZIK "plasmatis" will be continued in a second funding phase with two new junior research groups: "Plasma Liquid Effects" and "Plasma Redox Effects". The research groups of the first funding phase were made permanent and a self-funded junior research group in the field of biosensing surfaces was established.

The junior research groups independently pursue interdisciplinary research topics outside of operational activities or research contracts – an opportunity for junior researchers to gain initial management experience and build their own profiles.

ZIK plasmatis – Plasma Redox Effects

ZIK plasmatis – Plasma Liquid Effects

Biosensing Surfaces

Plasma Source Concepts

Plasma Wound Healing

Plasma Agriculture

Materials for Energy Technologies

ZIK plasmatis
Plasma Redox Effects

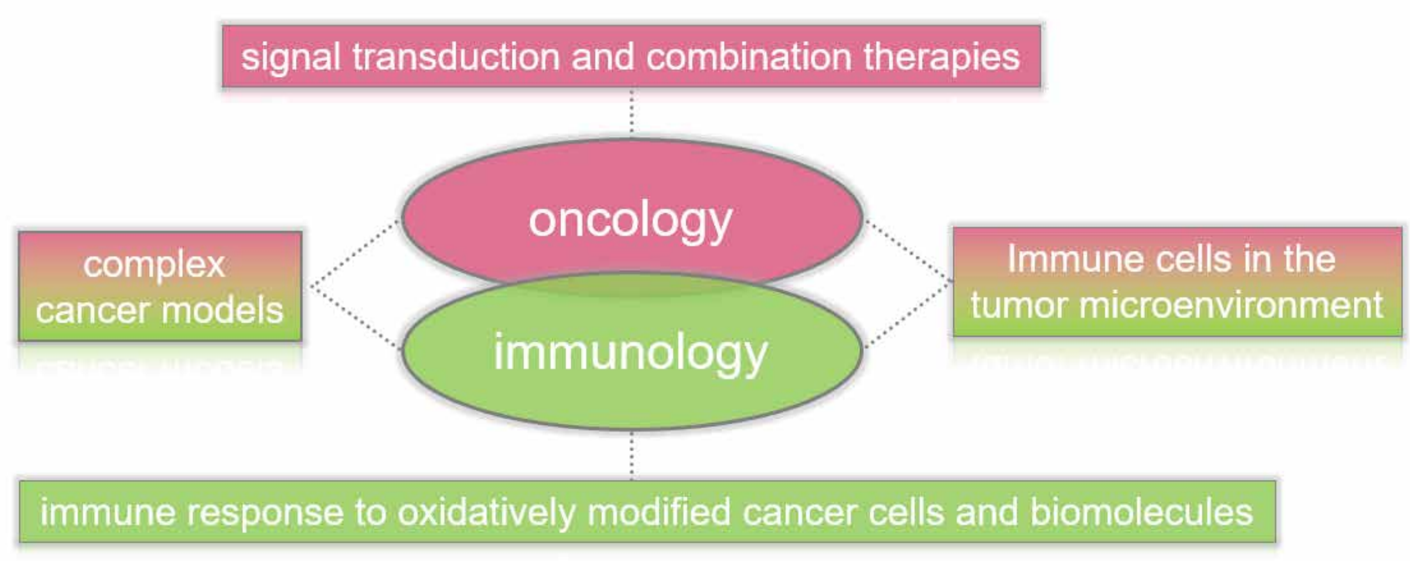

Fig. 1: Naming and connection of central research topics of the research group ZIK plasmatis "Plasma Redox Effects" (PRE).

Gas plasma-assisted wound healing has been established at the clinic. New therapeutic concepts in plasma medicine are being investigated in the "Plasma Redox Effects" group. The gas plasma jet kINPen developed at INP is used mainly for this purpose. One of these concepts is cancer therapy. But how can the two seemingly contradictory approaches be combined with the same technology?

The biological effectiveness of gas plasmas is based on their production of reactive oxygen and nitrogen species, which are commonly referred to as "free radicals". In lower concentrations, these compounds act as signal molecules in cells and support cell growth, which is required for wound healing. However, at high concentrations, the toxic effect predominates and causes cells to undergo cell death, which is necessary in cancer therapy. Because the amount of radicals produced during treatment with the kINPen depends on the treatment time per unit area, this technology can stimulate wound healing with short treatment times and kill cancer cells with long treatment times. Our hypothesis can be derived directly from our results at the ZIK plasmatis: For the stimulation of wound healing with the kINPen in mice, 5 seconds treatment time was required; for the successful reduction of tumour growth in mice, at least 20-fold this time was required.

The elucidation of the mechanism of the killing plasma effect in tumour cells is a focus of the research group. Previous results show that mitochondria can multiply the effect and that intracellular signalling pathways (e.g. HMOX1) are a signature of treated cells of different tumour types. The second focus is the combination of gas plasma with other processes. We were thus able to show that there are positive combination effects with ionising radiation, pulsed electric fields, and chemotherapy. For the latter, we found candidates for already approved compounds (e.g. doxorubicin and rapamycin) as well as substances still in development (e.g. the HSP90 inhibitor PU-H71). Many of our experiments are carried out in conventional two-dimensional cell culture models.

Our work also focuses on extending research models for plasma research. In cooperation with the Surgical Research Laboratory of the University Medical Centre of Greifswald, we were able to use the 3D tumour spheroid model for our experiments. The Institute of Pharmacology has kindly allowed us to carry out our tumour experiments in rodent models in their facilities for two years. These models are particularly relevant because the immune system is active only in the organism as a whole. The effect and relevance of the immune system in tumour defence was awarded

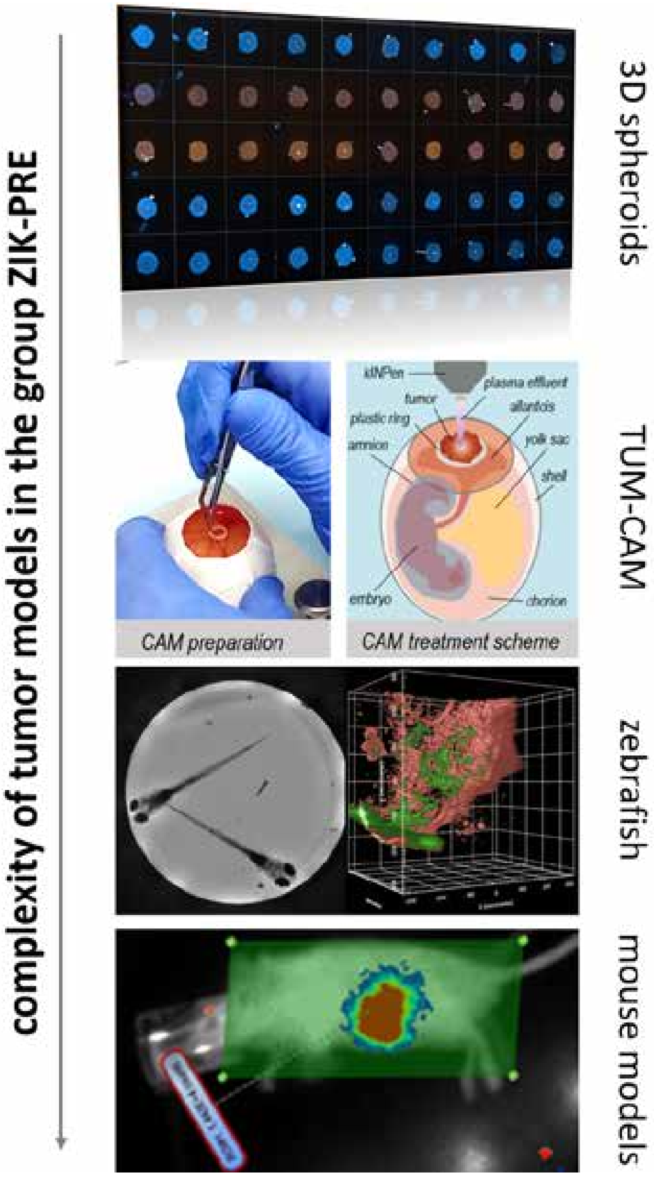

Fig. 2: Various complex biological laboratory models for research on anti-tumour response and immunological questions, which are used in the group ZIK plasmatis "Plasma Redox Effects" (ZIK-PRE).

the Nobel Prize for Medicine or Physiology in 2018. Its importance is thus undisputed. At the same time, anti-tumour immune defence can be specifically studied in animal models only. In 2018 and 2019, we showed that the plasma-assisted treatment of melanomas in the mouse model results in an increase in the number of intra-tumour immune cells. Immune cells themselves represent another important field of investigation for us. We were able to show that plasma treatment phenotypically alters scavenger cells of the immune system, making them more toxic to tumour cells. The surface markers of tumour cells can also represent "alarm" signals for immune cells. We have also seen an increase in such signals because of the plasma treatment of tumour cells. The next step is to study the tumour cell-immune cell interaction in more detail and to better understand the immunogenicity of these cells and of proteins after plasma treatment in the context of oxidative changes.

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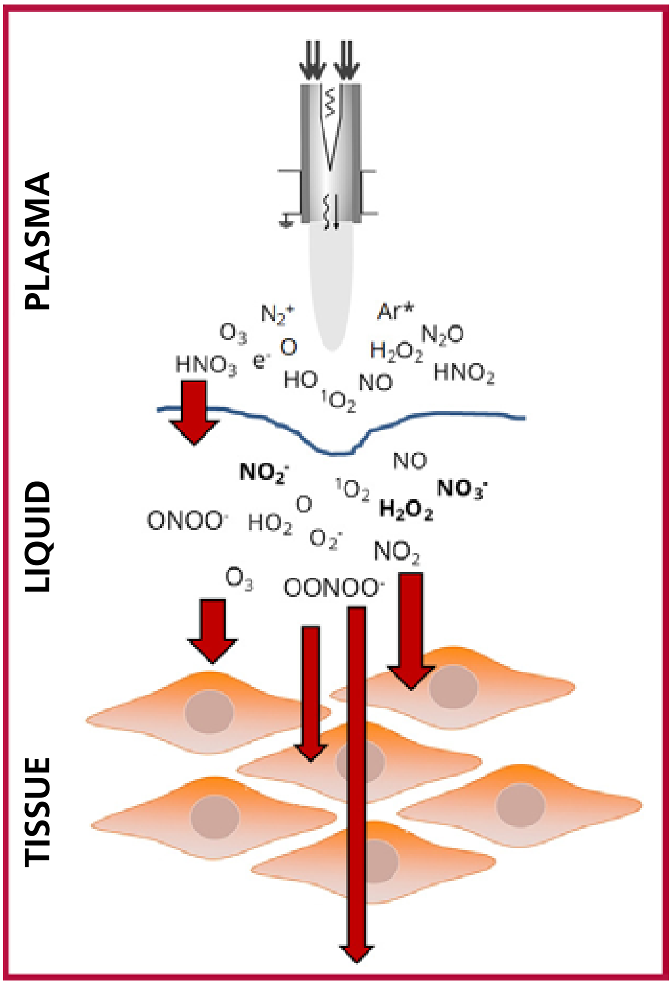
ZIK plasmatis
Plasma-liquid effects

The junior research group "Plasma Liquid Effects" would like to investigate the following question: Is it possible to identify individual redox-active species that are mainly responsible for special biological effects by detailed analysis of the interaction of cold plasmas with liquids or tissues?

This requires a better understanding of the complexity of the chemical processes stimulated by plasma treatment in aqueous systems. The focus is on the biochemical analysis of liquids and biomolecules. In collaboration with plasma and gas phase diagnostics, the main reactive species deposited by plasma into liquid biological systems will be identified. Together with the "Plasma Redox Effects" group, the functional consequences of their occurrence for human or animal tissue will also be investigated. The aim is to identify the essential parameters required to generate the tailor-made "cocktail" of active plasma species for a desired application.

Cold plasmas are finding increasingly more clinical applications (e.g. in chronic wounds, throat infections, and malignant diseases). Other areas of application (e.g. psoriasis) are also being investigated. The connecting element in all these disease patterns is the occurrence of inflammatory processes and the essential role of the immune system. The biochemical processes involved are not yet fully understood. However, the activity of reactive oxygen and nitrogen species (ROS/RNS) plays a key role here. These compounds are embedded in various signal transduction processes of cells and tissue (redox signalling), including NF-κB (nuclear factor 'kappa-light-chain-enhancer' of activated B-cells) and related signalling pathways, the WNT (Wingless/Int-1), MAPK (mitogen activated protein kinases), Keap1-Nrf2 (cup-like ECH-associated protein 1/ nuclear factor (erythroid-derived 2)-like 2), and the ubiquitin/proteasome system (UPS). Post-translational modifications (PTMs) of biomolecules play a role in all these protein signalling chains (e.g. through the oxidation of protein-containing thiol groups or the nitrosylation of cysteine or aromatic amino acids and lipids. Depending on the molecule, this leads to a loss or gain of function and the subsequent influencing of enzyme activities. By feedback loops and reductive processes (peroxiredoxins, thioredoxins, glutathione), the signal is switched off again. The free concentration of the important messenger substance H_2O_2 does not exceed 10 nM within the cell. Superoxide and the RNA peroxynitrite or NO are also compartmentalised and their concentrations regulated. This enables the cell to react decisively and precisely to changes in ROS/RNS concentration. The cellular processes modulated by these species range from cell cycle and cell division to cell maturation and cell ageing to cell migration. The failure of redox signalling leads to pathological processes, including unrestrained growth and premature cell ageing.

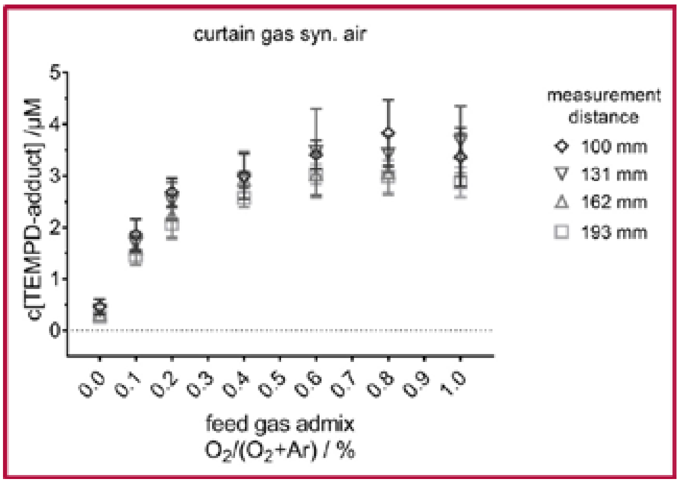


While the composition of the gas phase of cold plasmas is already well understood, the transport of reactive species through the boundary layer to the liquid and further into the cell/tissue must be further investigated. This is the task of the ZIK-PLE group.

Cold plasmas produce a variety of reactive species, including ions and excited states of the carrier gas and free electrons as well as ionic or neutral states of heteroatoms or resulting molecules. These include various states of oxygen such as atomic O, the superoxide anion radical, singlet oxygen, and ozone. Molecular oxygen is present either as an admixture or penetrating laterally into the effluent. While much is known about its distribution in the gas phase by simulations and FTIR measurements, there is uncertainty about its role in liquids. In order to get a better understanding, a number of diagnostic tools have been used together with international partners. These include electron spin resonance (H. Jablonowski, INP), absorption spectroscopy in the gas (H. Jablonowski/INP and Joao Sousa/LPPG Paris Sud) and liquid (H. Jablonowski/Alec Wright & Felipe Iza, Loughborough University) phase, and emission spectroscopy.

With an admixture of oxygen to the working gas and an oxygen sheathing around the jet in the far field (≥ 100 mm to 224 mm), it was shown that ozone is dominantly detectable in the gas phase as well as in the liquid. Even if the gas sheath around the effluent consists of nitrogen, this is still the case to a lesser extent. Singlet oxygen is found only in the case of the nitrogen sheath, and the concentration in the gas phase is distance dependent unlike ozone. In the liquid (a physiological buffer), which was treated with the far field of the jet (> 100 mm), a strong, distance-independent increase in the EPR signal was measured via TEMPD (2,2,6,6-tetramethyl-1-piperidinyl). This indicates the presence of ozone. This was confirmed using the Pittsburgh Green dye developed in Loughborough. However, if the buffer was treated at a short distance (9 mm), ozone did not occur, and the EPR signal showed congruence with singlet oxygen emission.

Especially when using the nitrogen sheathing, the significant increase of the EPR signal was associated with the solution of singlet oxygen in the liquid. However, further experiments are required in order to prove this. However, the TEMP signal in the liquid may have been caused by atomic oxygen in addition to $^1O_2$ and O_3. Its effectiveness in biological systems has been demonstrated in cooperation with Peter Bruggeman (University of Minnesota) and again by Bekeschus, Wende, and Benedikt (University of Kiel). In the ZIK-PLE group, experiments using chemical tracers are being performed to verify these results.



Electron spin measurement of ozone in physiological fluids. Depending on the admixture of oxygen to the working gas and independent of the distance (> 100 mm), the TEMP signal increases significantly. The presence of ozone under these conditions was confirmed by measurements using a specific dye.

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Biosensing surfaces

In an interdisciplinary research environment at the interface of polymer chemistry, material sciences, and plasma technology, the junior research group Biosensing Surfaces (BSO) works on the development and characterisation of novel functional layers for applications in medicine, biotechnology, environmental analysis, and food technology.

For biosensing and microfluidic applications, the control of physical, chemical, and biological interface properties is essential to ensure the best possible performance in interaction with the biological environment. Plasma-assisted surface processes give materials new properties by generating surface functionalities or by depositing thin films.

Plasma printing

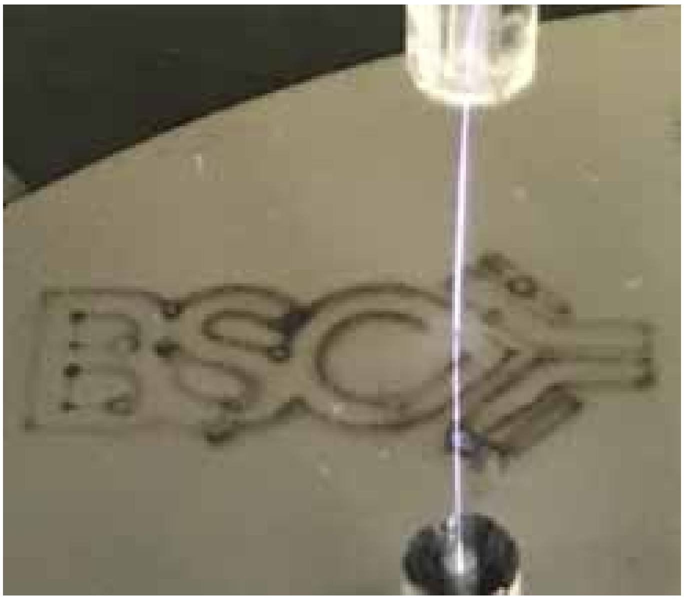
Chemically structured surfaces in the sub-millimetre to micrometer range prove to be a particularly valuable platform in the field of microfluidics.

The liquid volumes are now in the microlitre or even nanolitre range. This allows microfluidics to drastically reduce sample and reagent volumes, speed up reactions, and thus increase throughput and enable resource-saving measurements. The use of multiplex arrays is thus of particular interest because they allow the simultaneous processing of a large number of analytes on a single microchip. This requires areas of defined chemical and physical properties that can be produced on any surface – for example by means of a plasma printing process developed in the junior research group Biosensing Surfaces. This innovative process enables a site-selective deposition of plasma polymer coatings with structural dimensions from 150 µm and film thicknesses in the range of 20 to 150 nm using an atmospheric-pressure plasma jet developed at the INP.

Functional layers

The core of every biosensor is the biological recognition structure, which can consist of an enzyme, an antibody, DNA, or entire cells.

In order to selectively detect the analyte in the sample, a surface modification of the biological recognition layer is necessary. The surface chemistry of the recognition structure must be such that no unspecific interactions occur and that there is targeted coupling of the analyte binding partner on the sensor surface. Especially for measurements in real samples it is crucial that the functionalised surface has a sufficient immobilisation density and a sufficiently high binding activity so that even low concentrations can be detected.



Photographic image of the plasma jet during the generation of the chemical structure on a silicon wafer (plasma printing process)

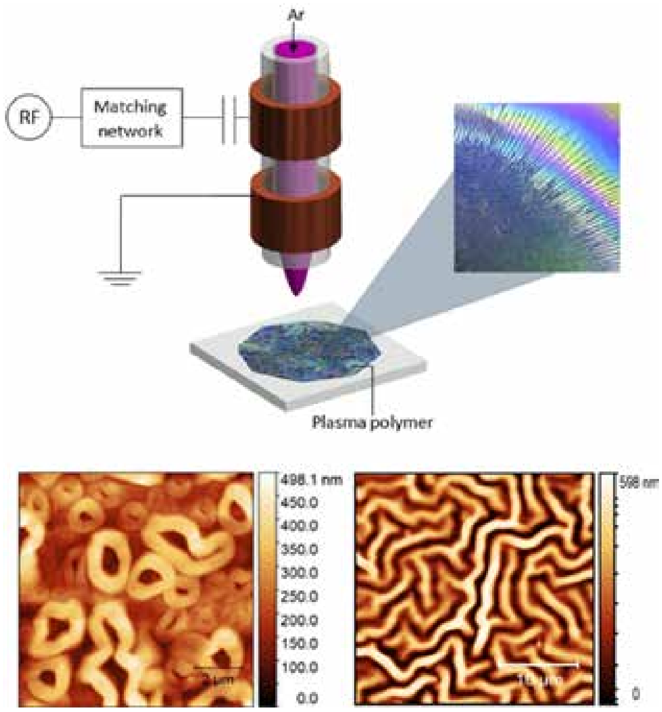
One focus of the junior research group BSO is the generation of thin plasma polymerised films enriched with oxygen-containing functional groups.

Investigations on the chemical composition, morphology and stability of the plasma-polymerised films in an aqueous environment showed a unique functionality and excellent adhesion to the substrates. The SPR immunosensors efficiently immobilised antibody molecules, thereby resulting in a selective and excellent response to the analyte and a high degree of stability. For all immune sensors, a detection limit of 50 ng/ml HSA was achieved.

Synthesis of thin hydrogel coatings

Because of their stimulus-responsive properties, hydrogels are ideal for applications in microfluidics and medical technology. Due to their high water content and tissue-like mechanical properties and the resulting biocompatibility, hydrogel films are also suitable for the development of biomedical (implantable) sensors.

The work of the junior research group BSO includes the synthesis of hydrogel coating by plasma polymerization at atmospheric pressure. For example, acrylate-based hydrogel films of thicknesses as low as 10 µm were generated. These exhibit a controlled and reversible swelling behaviour depending on the pH value. Investigations have also shown that the targeted adjustment of the film thickness and the associated characteristic wrinkling favours the immobilisation of biomolecules. A high reproducibility and long-term stability was sought for the coatings obtained. By characterizing the coatings, the application areas are to be determined, and their future use as a multi-sensitive sensor layer is to be examined.



Schematic representation of the experimental set-up for the generation of functional coatings and hydrogels.
AFM images of the plasma polymerised coatings show different surface topographies that can be used for the immobilization of biomolecules.

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Plasma Source Concepts

The research group "Plasma Source Concepts" emerged from the former junior research group "Extracellular Effects". Its work focuses on the following issues: Is it possible to design plasma sources optimally adapted to specific medical applications on the basis of the available findings, or can new concepts be developed for specific applications?

In addition to the experiences and the fundamentals from the "Extracellular Effects", the technological requirements of the conception, development, and design of medical plasma sources were particularly taken into account when founding the "Plasma Source Concepts". To address the technological tasks, employees of the deparment Plasma Sources, who were previously particularly involved in the projects for the development of medical plasma sources, were included in the group. The description for "Plasma Source Concepts" as spin-off from the department "Plasma Sources" as well as the integration of the "Extracellular Effects" is appropriate here.

With the fundamental research findings now available, there is a sound scientific approach to designing new plasma sources that are tailored to clinical needs.

The work of the research group "Plasma Source Concepts" should lead to fundamentally new findings. The aim is to analyse how the components generated by the plasma adjust so that the biological processes can be modulated. Here there is a direct interaction with the work of the junior research groups of the ZIK Plasmatis "Plasma Liquid Effects" and "Plasma Redox Effects".

The concept of the research group "Plasma source concepts" includes the development of novel source concepts for plasma generation via the targeted control of electrons, thus enabling the direct control of plasma chemistry and new source geometries. In order to achieve the desired goals, we will continue to work closely with the Plasma Sources Department at the INP and the Karlsburg Diabetes Centre of Excellence (KDK).

Various industrial contacts and projects are integrated into the work in order to be able to adapt the concepts to the manufacturers' requirements at an early stage. By moving into and commissioning the laboratories at KDK in November 2018, company contacts have been intensified and new networks have been established.

With the fundamental research of the "Plasma Source Concepts", the diagnostic focus is place on the determination of the "plasma cocktail" of active species. Especially the ion density measurement and the determination of the electric field component turn out to be unaddressed. The feedback of the relevant components into the source development closes the circle from fundamental research to application.

Further control of the electric field strength is achieved by adjusting the dielectric barrier by putting a 3D printer into operation, which enables the high-precision production (about 0.05 mm) of small quantities from a wide variety of materials and thus sets no more limits to innovative freedom.

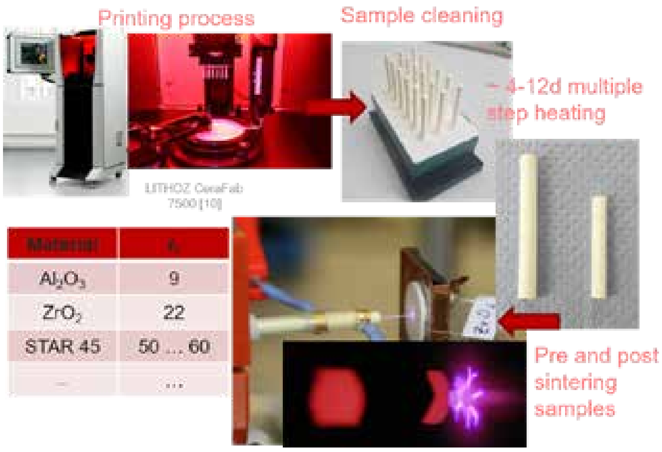

Figure 1: Production cycle of a 3D printed ceramic made of alumina as well as ignition example.

The electrical properties have already been investigated in a first Master's thesis. 3D ceramic printing also opens up great future potential for collaboration with working groups of all areas at the INP because it addresses a central component of plasma technology.

Further aspects of fundamental research are the determination of the power fed into the plasma on the device side for process control as well as for better comparability of individual treatments. In addition to the aspect of power measurement, one Master's thesis is dedicated to the interaction of the plasma with the surface. It is being investigated how the plasma sources adjust to surfaces of different dielectrics and how the power input can be influenced. In a further step, the impact of the change of power input on the ozone production was investigated and correlated using FTIR.

With regard to application, the "Plasma Source Concepts" research group responds to various industry requests and supports the strategic developments of the INP. The focus is on large-area plasma sources based on dielectric barrier discharges and plasma jet arrays. Plasma jets for localised treatment of spots that are sometimes difficult to access are currently being developed. Endoscopic applications are just as important as dental applications on the complex geometry of the oral cavity. One of these will enter the clinical trial phase in 2020. Further project proposals on these topics have been submitted.

For the design and construction of laboratory samples, the portfolio of possibilities for the use of various materials is continually being expanded. The new equipment for the laboratories of the KDK should be mentioned in particular. In addition, the portfolio of rapid prototyping is constantly being expanded in cooperation with the Plasma Sources department.

The development of a mobile sensor unit was thus initiated. In cooperation with students of the University and University of Applied Sciences in Lübeck, this paves the way for outpatient plasma application.

Over the next few years, it is planned to open up the portfolio of functional models at INP for transfer to industry. Talks are currently being held with industrial partners. These could lead to further bilateral or funded projects. Thus, the adaptation of the plasma sources to different fields of application is to be carried out by industrial support.

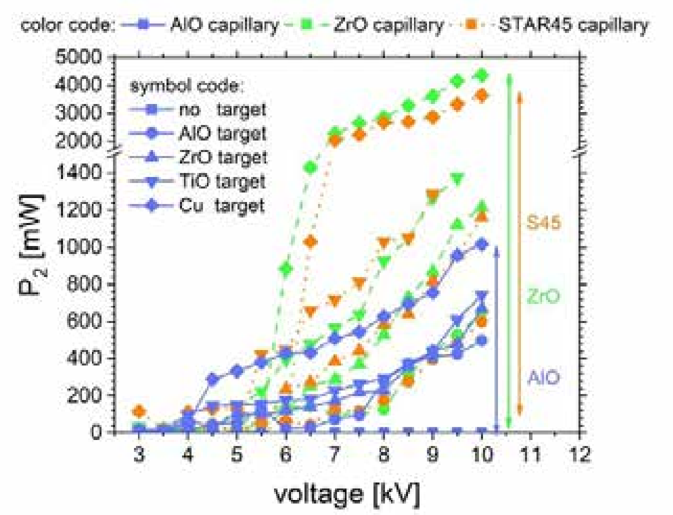

Figure 2: Power input of an inductively coupled plasma jet onto a surface by varying the dielectric of the surface and the capillary wall.

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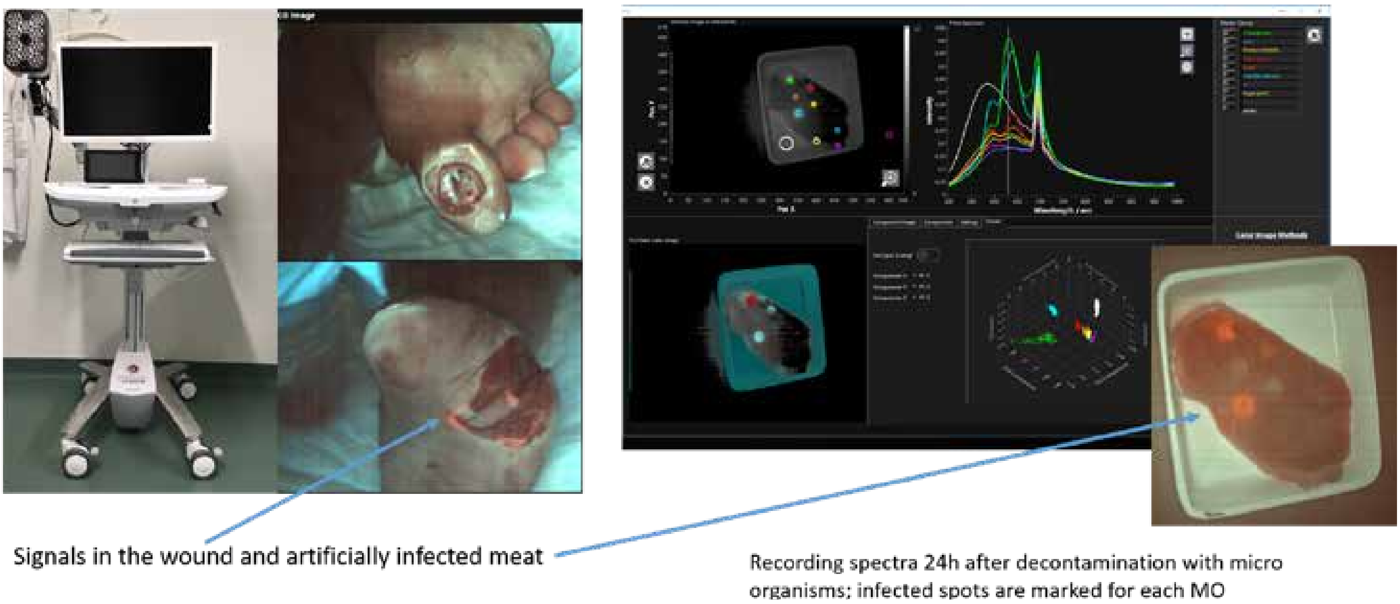
Plasma Wound Healing



Plasma treatment of a diabetic foot with chronically infected wound

The research group "Plasma Wound Healing" deals with the question: Does the wound healing effect of cold plasmas depend on the aetiology of the wounds or also on the spectrum of microbiological colonisation? Furthermore, the individually optimised plasma treatment of different patients and their specific wounds plays a central role in the applied clinical research.

Cold plasmas are complex mixtures of free electrons and ions, UV radiation, visible light, heat, and numerous excited species. Especially 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 influence the cellular redox balance and can be adjusted to either stimulate or kill cells depending on their composition and the duration of treatment. Here, the sensitivities of the treated cells differ greatly. This is due to different antioxidative potentials of the different cell types and their ability to regenerate. Cold plasmas are therefore suitable for killing bacteria. Here, multi-resistant germs show the same reduction rates as non-resistant strains. It has been shown that a balanced plasma treatment of human cells can also lead to their stimulation.

The aim of the "Plasma Wound Healing" research group is to transfer the basic research results into the clinical practice of wound treatment. Special attention is given to deepening and adapting the research results of the ZIK plasmatis on wound healing by finding differences between human cells and the micro-organisms found in chronic wounds. The aim is to identify molecular differences in radical defence, metabolism, and cell repair between human skin cells as well as the immune system and the micro-organisms in the wound. For this purpose, wound swabs – also known as exudates – are taken and examined for their cellular and soluble components.

For these investigations, the Karlsburg Diabetes Centre of Excellence (KDK) works in close cooperation with the Klinikum Karlsburg. The aim is to develop a plasma treatment tailored to the patient or wound in order to further optimise wound healing with the aid of cold plasmas.

The clinical examinations include detailed analyses of wound exudates. These are supplemented by imaging, microbiological smears, and the analysis of messenger substances (growth hormones, cytokines). This should help to optimise the camera system (BacteriaCam) as well as provide information as to whether plasma treatment leads to growth stimulation.

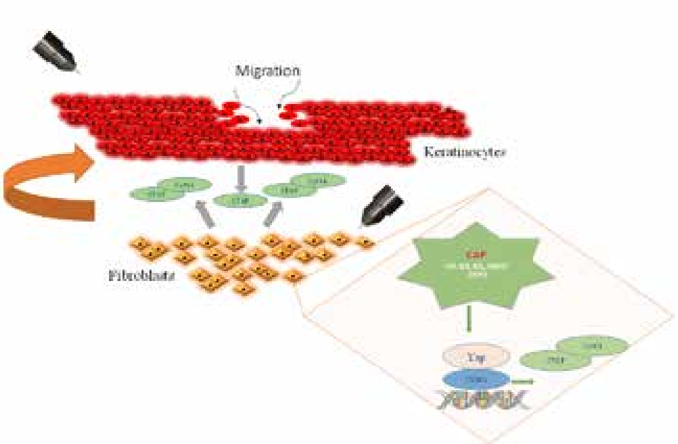
Another focus was the analysis of a new signalling pathway, the HIPPO pathway, which has not yet been investigated in relation to plamsa treatment. Here, too, new insights into the effect of cold plasmas on skin cells have been gained.

Increasingly more studies are focusing on paracrine signal transmission and interaction between keratinocytes and fibroblasts for wound repair. To prove our hypothesis that cold atmospheric-pressure plasma (CAP) induced stimulatory effects in co-culture are a result of paracrine crosstalk, we monitored cell migration of HaCaTs incubated with conditioned media derived from CAP-treated GM Fbs (GM Fb CM) collected after 18 hours of CAP treatment. GM Fb CM was able to accelerate the migration of HaCaT cells more than CM obtained from untreated Fbs and no CM at all. This phenomenon supports our hypothesis that CAP induces paracrine signal transduction between these two cell types by releasing paracrine effectors, thereby promoting keratinocyte migration. As expected, we also demonstrated an increase in secreted CTGF and Cyr61 expression in plasma-treated GM Fb CM. The HaCaT monoculture treated with recombinant CTGF and Cyr61 also showed improved cell migration. In particular, these data show that CTGF and Cyr61 secreted by CAP-treated Fbs act as paracrine effectors in wound healing.

These results further confirm our hypothesis that CAP promotes a beneficial interaction between keratinocytes and fibroblasts, which in turn contributes to wound healing.

Here we have shown for the first time that CAP can stimulate a regenerative signalling pathway in dermal cells. We observed that the cold plasma-mediated effect on skin repair is mainly due to the activation of fibroblasts which, once stimulated by CAP, show a paracrine stimulation of keratinocytes as demonstrated by our co-culture experiments. Together, these results confirm the role of CAP as a potential clinical therapy that has a direct stimulating effect on tissue regeneration.

Based on the data available, an overview of the effects of CAP treatment on cellular redox signalling is provided



Exemplary presentation of the microbial analysis of wound swabs on selective agar.

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Plasma Agriculture

The "Plasma Agriculture" (PAK) research group develops innovative plasma processes with the aim of increasing the resistance of plants to abiotic and biotic stress factors before harvesting accompanied and assuring growth and yield. The biological decontamination of seeds using plasma-based technologies is another central topic. This can improve the storage and transport of seeds. In addition, plasma treatment can have a stimulating effect on plant germination, especially in poorly germinating plant species such as legumes. The underlying processes of stimulated seed germination and improved resistance of plants are investigated both in fundamental and applied research.

The research group, which began its work in summer 2017 with the appointment of Dr. Henrike Brust, plant biologist, and Dr. Nicola Wannicke, microbiologist, brings together an interdisciplinary team of scientists and technicians who contribute their expertise in plant biology, microbiology, plasma physics, and constructive plant engineering. Dr. Henrike Brust has headed the research group since September 2018.
The research group first plans to investigate the effects of direct and indirect cold plasma processes on plants and then develop suitable plasma sources. The results of these experiments then form the basis for applications in agricultural plant production. Against the background of the planned stricter EU regulations on plant protection products and climate change, alternatives that will make it possible to reduce the use of chemicals in the fields are to be developed. The reactive oxygen and nitrogen species (RONS) contained in many physical cold plasmas have already been identified as important active components on animal and human tissue in plasma medicine. RONS also play an important role in the life cycle of plants – both as signalling and defence molecules in growth and development processes as well as in defence reactions against abiotic and biotic stress.

In addition to the knowledge gained in plasma medicine on the effects of cold plasma on the redox biology of animal and human systems, the research group PAK can also build on the experience of the "Plasma Bioengineering" department. The department headed by Dr. Jörg Ehlbeck is working on cold plasma processes for the treatment of post-harvest food with the aim of microbial decontamination and preservation. In recent years, the methods have been successfully tested for fruit and vegetables, meat products, spices (e.g. pepper), and the seeds of various plant species. Joint work in the field of seed treatment with cold plasma for decontamination resulted in an initial joint publication in 2018.

The simultaneous preservation of seed germination capacity and young plant development is important in cold plasma processes, which aim at the microbial decontamination of the seed surface. The laboratory analyses of the PAK research group therefore include seed germination tests, the determination of germination rates, and the recording of biomass parameters for seedling development and growth. In addition, there are analyses of the seed surface such as hydrophilic tests, elemental analyses, and water absorption properties. These investigations are accompanied by microbiological work to test decontamination by cold plasma on the seed surface. At present, bacterial spores are used as model organisms for phytopathogenic fungal and mould spores.

First results suggest a stimulation of the germination rate, increase of the maximum germination for some legumes, improvement of the wettability of the seed surface, and a successful biological decontamination of the seed surface after plasma treatment. These results have been presented at international conferences such as the IWOPA2 2018 in Japan, the COPSA 2018 in Belgium, the IFFM 2019 in Korea, the CBrAVIC 2019 in Brazil, and the MRS-J 2019 in Japan.

An international exchange took place through the six-month research stay of Taiana Mui from Brazil. She investigated the effect of plasma on the germination of sunflower and barley. Stefanie Monge from Costa Rica conducted experiments on the effect of plasma-treated water on the germination and growth of barley and pea and successfully defended her bachelor thesis in December 2019.

In 2017, the Leibniz Institute for Plasma Science and Technology (INP) joined forces with the Neubrandenburg University of Applied Sciences and successfully applied to the BMBF program "WIR! – Change through Innovation in the Region" with the jointly developed project "Physics for Food – a region is changing its way of thinking!". Launched in 2018, the project uses innovative physical high technology to shape structural change in the coastal hinterland North-East region, which is characterised by the traditionally established agriculture and food industry. Both research institutions can look back on many years of cooperation in which they have pursued the joint development, production, and marketing of plasma-based systems for the sterilisation of food.

Over a total funding period of 5 years (until 2024), the consortium of 60 alliance partners will pool existing research and development potentials in the region and thus introduce innovative physical methods – from plant cultivation to the processing and refinement of plant agricultural raw materials – into the entire value chain by means of appropriate technology developments. In September 2018, "Physics for Food – a region is changing its way of thinking!" was presented for the first time at the user-oriented agricultural exhibition MELA in Mühlengeez in Mecklenburg-Western Pomerania. It was presented at another exhibition in 2019, and more presentations will follow.

Over the next few years, the PAK research group will establish plant-physiological and phytopathological methods in the laboratory in order to be able to specifically investigate cold plasma effects on the abiotic and biotic stress adaptation of plants. The design and application of plasma sources with different electrical parameters as well as the characterisation of plasma sources with respect to temperature, reactive species, pH, and physical parameters will continue to be the basis for developing useful concepts for scaling up cold plasma processes for agricultural and industrial applications. These projects are embedded in the 12-month basic project started in September 2019 and will be implemented in the lead projects "Physics for Seeds" and "Physics for Crops" of the WIR! project "Physics for Food – a region is changing its way of thinking", which will start in summer 2020.

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Materials for energy technology

The Research Group Materials for Energy Technologies (MET) is a multi-disciplinary team in the science triangle of plasma technology, materials and chemical engineering. It focuses on the development of cost-effective and scalable synthesis routes to produce nanomaterials and thin films for the storage and conversion of renewable energy. Our materials are used in electrolysis as well as battery and fuel cell technology and are brought into technology transfer within partner networks of institutes and companies. Important core expertise and know-how from the INP departments "Plasma Process Technology" and "Plasma Surface Technology" (vacuum deposition, plasma spraying, and plasma polishing) as well as "Plasma Sources" (pulsed high voltages in liquids) flow into the development. Another important pillar of our work is the characterization of the crystal and nano- or microstructure of materials by XRD, TEM/SEM, EDX, XPS and Raman spectroscopy as well as a screening of the electrochemical properties (e.g. by cyclic voltammetry and impedance measurements).

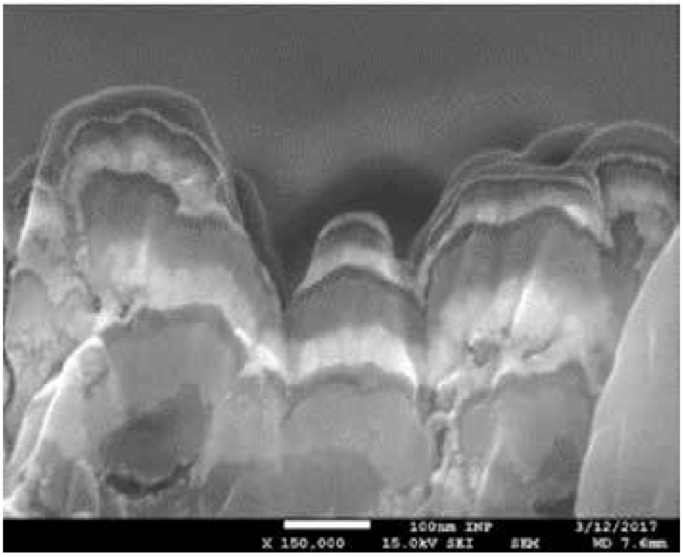
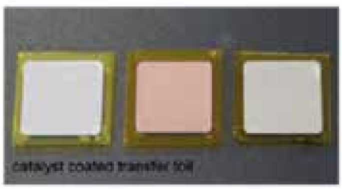


Figure: Development of a low-cost PVD process for the production of low Pt electrodes on a corrosion-resistant metal oxide carrier for polymer electrolyte fuel cells (PEMFC). Cooperation with ZBT - Zentrum für Brennstoffzellentechnik GmbH [https://zbt-duisburg.de/meta-menu/home/link].

Cost-effective methods

New plasma processes are being developed to produce ceramic thin films based on complex metal oxides (e.g. perovskite) and electrodes based on nanohybrids of metal-carbon or ceramic-carbon. Through cost and time efficiency, material flexibility, scalability to high-throughput processes, and good control of process parameters, plasma-assisted processes can meet the most important challenges in the research and development of new synthesis methods – the suitability of the manufacturing process for technology transfer to the market.



Electroceramic thin films

In our research group, vacuum deposition processes in combination with laser annealing for the generation of complex metal oxides with ABO3 perovskite structure on ceramic and metallic substrates are used to produce materials for energy technology. These oxygen- or proton-conducting membranes or mixed conducting electrodes are used for highly efficient energy conversion concepts for power generation and important future technologies for the production of emission-free fuels and energy storage as well as the conversion of these into electricity.

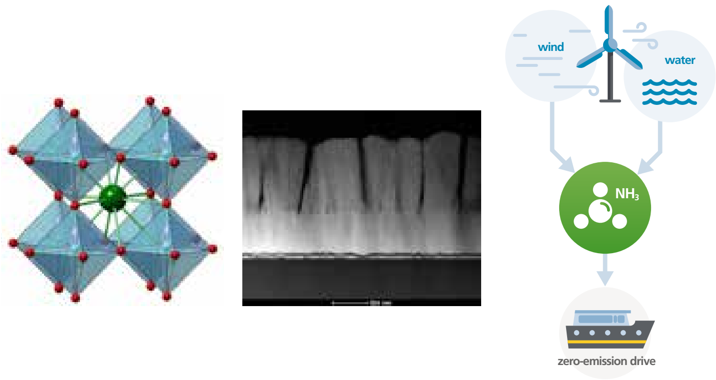


Figure: Left ABO3 perovskite structure with A = alkali or alkaline earth metal, B = transition metal. Centre: Transmission electron microscopy image of an electroceramic tungsten-based thin film [A. Müller, C. Scheu, MPIE [Link S. Scheu Group https://www.mpie.de/2902970/nanoanalytics_and_interfaces]. Right: CAMPFIRE: Wind and water to ammonia – maritime fuel and energy storage for an emission-free future [Link: www.wir-campfire.de].

Within the framework of the project WIR! "Change through Innovation in the Region" funded by the BMBF programme CAMPFIRE https://wir-campfire.de/, we are developing thin-film membranes and electrodes for the electrochemical production of the new energy source "Green Ammonia" together with our alliance partners. Ammonia is produced from atmospheric nitrogen and water by an electrolysis process using renewable energies. In the CAMPFIRE product category Maritime Mobility, it is used as fuel for engines or fuel cells in shipping. Further potentials of green ammonia are stationary energy storage and its use as a source material for green fertilisers.

2D materials

Two-dimensional (2D) materials have extraordinary electronic, optical, chemical, and thermal properties and are currently experiencing a high level of interest in various disciplines. In addition to inorganic 2D materials, such as transition metal disulphides or hexagonal boron nitride, graphene in particular is increasingly being researched as a high-performance material and used in many areas, including energy conversion and storage. Our team is developing a cost-efficient rapid bottom-up Plasma-in-Liquid (PiL) process of few-layer graphene from alcohol within the IGF project "GraphenBlocker" with the partners KIT and ZBT. The laboratory-scale batch plasma processes are further developed to continuous technical flow plasma reactors by fluidic and process optimisation. Furthermore, rapid top-down/PiL processes for the synthesis of 2D materials by exfoliation are being researched within the CarMON project "New carbon-metal oxide nanohybrids for efficient energy storage and water desalination" funded by the Leibniz competition together with our partners the Leibniz Institute for New Materials (INM) https://www.presser-group.com/ and the Max Planck Institute for Iron Research (MPIE) https://www.mpie.de/2902970/nanoanalytics_and_interfaces. The work task in the "CarMON" project is to investigate correlations between process conditions and the resulting crystallographic properties and performance in electrochemical applications.

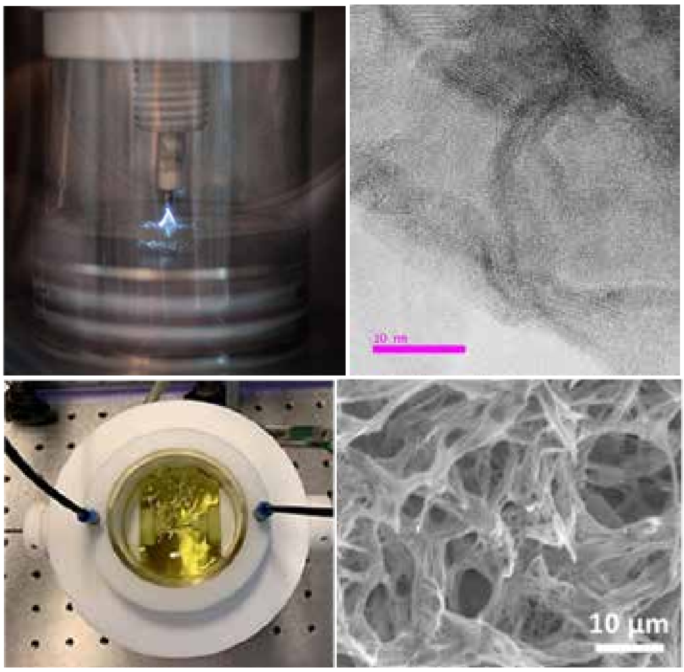


Figure: PiL process in tip-to-plate and tip-to-tip configuration for the synthesis of few-layer graphene and V2O5 nanofibres

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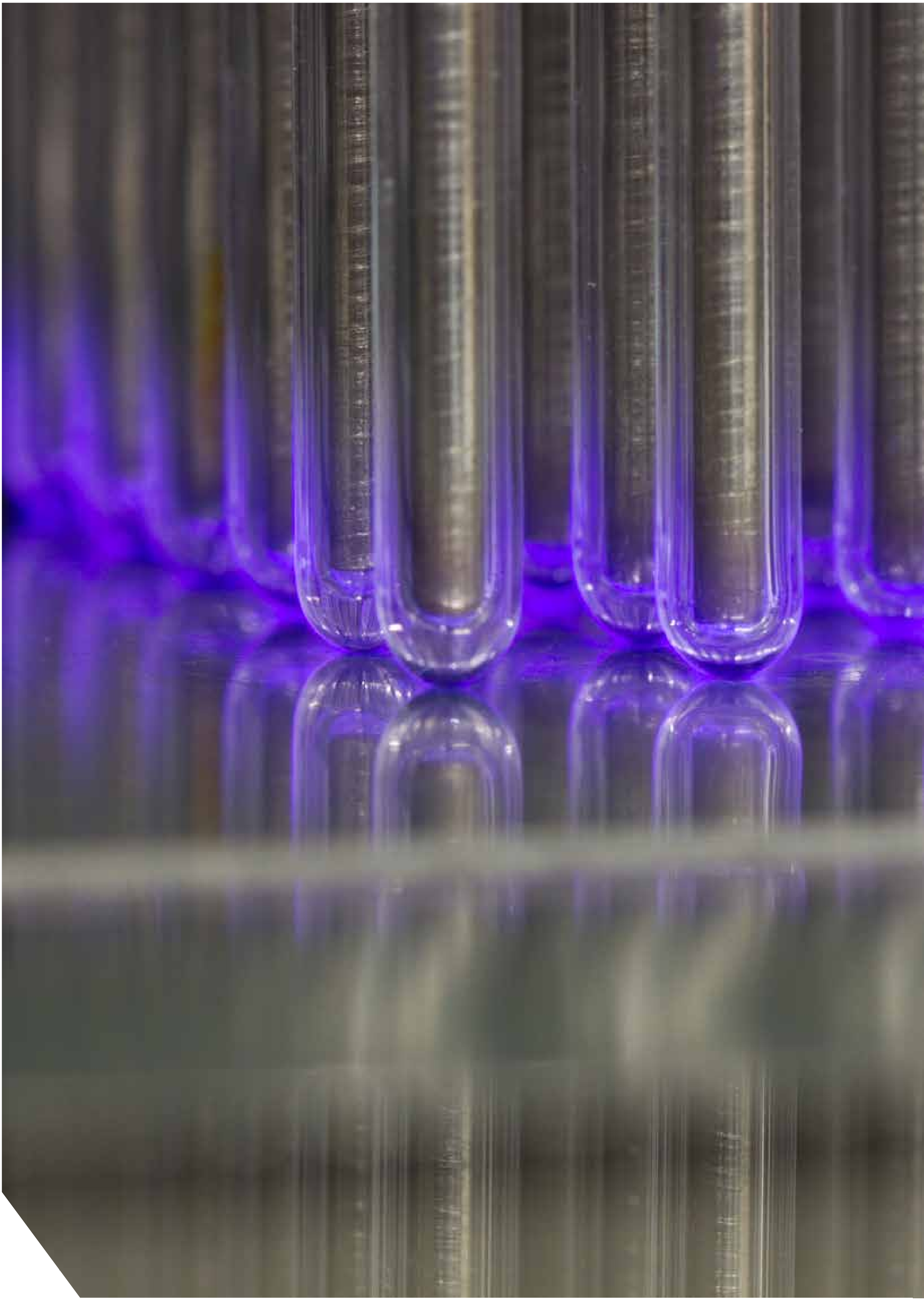
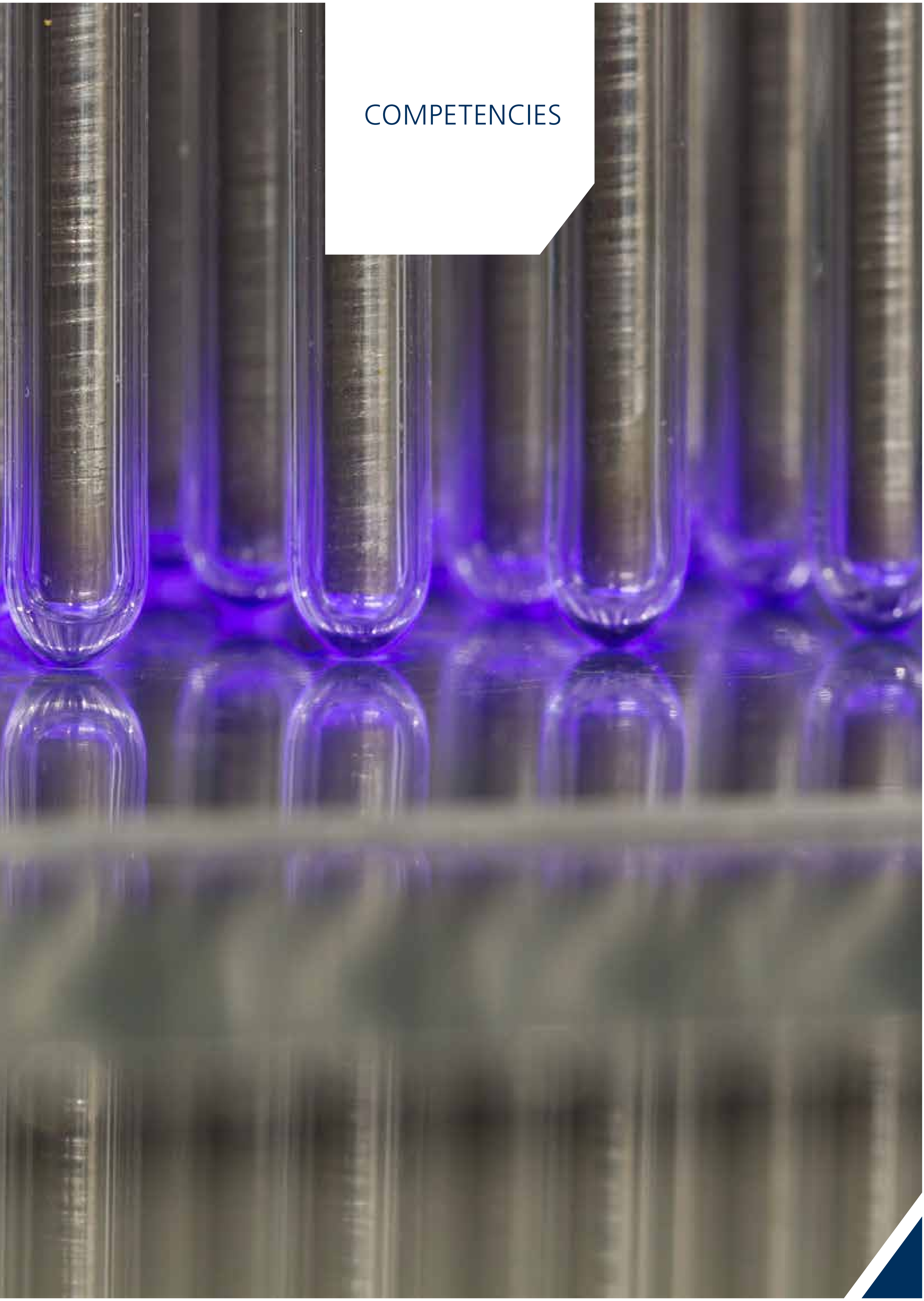


COMPETENCIES



Plasma Bioengineering

The Department of Plasma Bioengineering bundles the expertise in the process development of processes that are on the interaction of plasma with biological material.

For this purpose, expertise is available both in the development, adjustment, and diagnostics of special plasma sources optimised for the task at hand as well as in the diagnostics of the biological system treated.

In addition, the deduction and optimisation of the necessary procedures is another focal point.

Current topical emphasis is on the development of plasma processes for hygienisation in the post-harvest sector with a focus on the food sector as well as on innovative methods for process analysis and monitoring.

Examples of the current activities of the Plasma Bioengineering department are:

- the development of a hygienisation process based on Reactive Nitrogen Species (RNS), which allows both dry and wet treatment by means of a basic device.
- the development of optical sensors for process monitoring based on special diode laser systems.

The application-oriented research work is mainly carried out on the basis of joint projects with significant industrial participation.

Technological equipment:

Auxiliary Decontamination Unit (ADU):
Two-stage self-igniting atmospheric microwave excited plasma torch for RNS process gas generation (plasma processed air – PPA) with process control for operation of peripheral devices, capacity: 100 slm. Units for the production 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, and meat products in batches of up to 200 kg

Fluid bed dryer with plasma gas generators (ADU)

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

microbiological methods
- Proliferation assays
- Live-dead determination
- Biofilms
- Micro-organisms of RG1 and RG2

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

Treatment device for products in RPC (reusable plastic container) with plasma gas generator (ADU)

Optical measurement technology
- Optical emission spectroscopy (OES)
- Fourier transform infra-red spectroscopy (FTIR)
- Thermometry
- Laser diode absorption spectroscopy
- Fluorescence microscopy

High-frequency measurement technology
- Various spectrum and network analysers from 10 Hz to 50 GHz
- Microwave interferometer

Flow simulation
- Numerical flow simulation based on StarCCM+

CAD construction

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Plasma Diagnostics

The scientists and researchers of the Department of Plasma Diagnostics focus their application-oriented research activities on process monitoring and process control, especially in molecular plasma processes. Here, both fundamental and application-relevant questions in the field of materials and energy are addressed. 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 the most modern methods and is continually expanding the existing expertise as well as the spectrum of measuring devices and methods, in particular laser-based plasma diagnostics. Spectroscopic problems are investigated in the spectral range from ultraviolet to terahertz.

The application of modern methods of plasma diagnostics is the key to understanding complex plasmas. Molecular plasmas, which contain many different species, are characterised by numerous interesting and useful properties. Their wide-ranging technological applications range from resource-saving surface treatments (e.g. in the semiconductor industry) to disinfection and sterilisation processes, exhaust gas cleaning and gas scrubbing, particle decomposition, and the treatment of water, air, and hazardous waste.

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

In addition to the characterization of plasma processes to answer fundamental and application-relevant questions, the department also uses and develops diagnostic methods for monitoring and controlling technological plasma processes. Transfer projects (e.g. the SAW VIP-USD Transfer Project funded by the Leibniz Association) utilise resonator-based absorption spectroscopy with quantum cascade lasers. Based on a validated demonstrator (RES-Q-Trace), which is part of a BMBF-funded VIP project, a new class of devices for research and industry will be created in order to develop a prototype of a compact, transportable, and ultra-sensitive (ppt sensitivity) trace gas sensor. Potential applications include the monitoring of technological processes and pollutant emissions, the analysis of respiratory gas, and the detection of hazardous substances.

RES-Q-Trace – demonstrator of a resonator-based, quantum cascade laser-based trace gas analyser for highly sensitive trace gas detection.

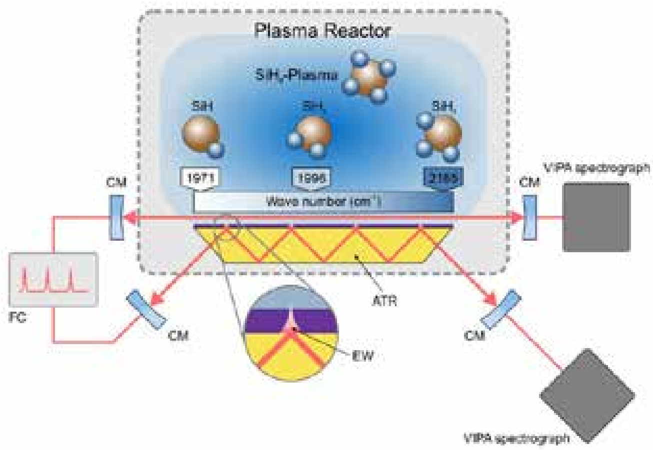
Specially equipped laboratories for diagnostics of laboratory scale chemical plasma processes with state-of-the-art measuring equipment are available for the investigations.

The following methods are used to quantitatively determine important parameters (e.g. species densities and their temperatures and the energy distribution of charged particles) and to characterise all relevant chemical reaction paths:

- Laser-induced fluorescence and absorption spectroscopy with coherent light sources in the spectral ranges:
  -- UV-VIS: pulsed dye laser
  -- Mid-IR: diode laser, quantum cascade laser, interband cascade laser, lead salt laser, frequency comb laser system
  -- THz: Quantum cascade laser
- Resonator 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 to 200 amu)

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

The first-time use of ultra-modern frequency comb systems (FCs) in the mid-infra-red spectral range will open up new opportunities for elucidating plasma-surface interactions. FCs are to be used as radiation sources in broadband, resonator-based direct frequency comb spectroscopy (CE-DFCS). This method will allow the simultaneous detection of a large group of transient reactants in the immediate vicinity of the surface.



Schematic approach for the simultaneous monitoring of the plasma boundary layer and the substrate surface using CE-DFCS.

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Plasma Life Science

In Plasma Life Science the effects of cold atmospheric-pressure plasma on living organisms are investigated with a focus on biological effects. Living organisms are diverse in this context and range from micro-organisms, micro-algae, and mammalian cells to tissues. Application-oriented research is of particular interest here. The basic principles of the use of plasma for therapeutic purposes are being investigated. On the other hand, the antibacterial effect of plasma is the focus for decontamination. More recent approaches combine plasma and biotechnology in the field of biopharmacy. In microbiology, it entails the inactivation of bacteria and fungi in different environments (i.e. liquids, surfaces, and air). In the field of cell biology, the aim is to modulate cell metabolism by means of plasma in order to substantiate clinical application or to open up new applications. New plasma sources are also tested for their biological effectiveness or antimicrobial effectiveness.

Technological equipment

Microbiology:
Laboratories that are equipped for all common microbiological examinations (e.g. spiral plate system for the quantitative determination of the living cell count, safety workbenches for sterile work, and spectrophotometers for the determination of the optical density). An existing strain collection includes various bacteria, yeasts, and fungi. Plasma sources to be tested can be set up in the laboratories and connected to the in-house gas supply.

Fluid analysis:
Various chromatography systems such as IC (ion chromatography) and HPLC (high performance liquid chromatography) are available. These devices can be used to investigate changes in ion composition (e.g. nitrate, nitrite) or special substances such as amino acids in plasma-treated liquids.

Protein analysis:
Various techniques are available for the analysis of cell metabolism and the regulation of protein expression. In addition to standard methods of protein detection in multi-plate format (ELISA, photometric assays), Western blots using membrane transfer and high-throughput capillary systems are available.

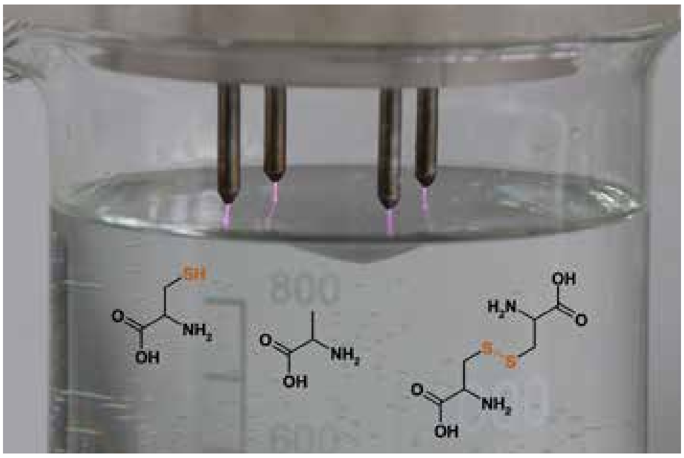
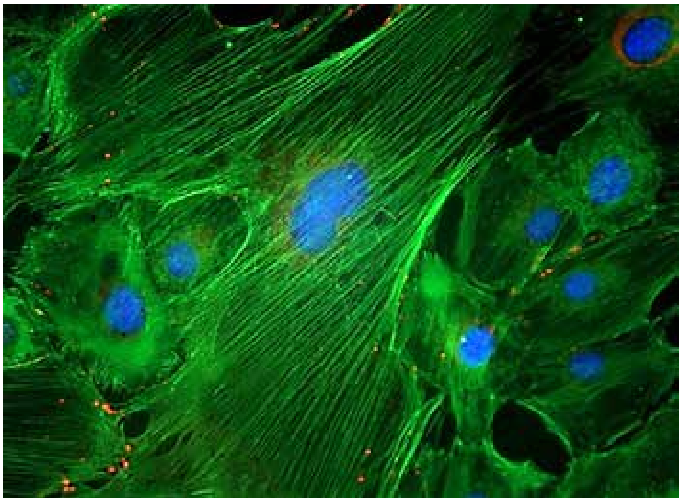


Illustration of plasma treatment of liquids containing substances such as amino acids

Pulsed electric fields:
Expertise and equipment to study the effects of pulsed electric fields on biological systems, especially cultured cells or micro-algae. For this purpose, an electroporator, including cuvette stand, is available to generate pulses in the range of microseconds to seconds. Furthermore, there are pulse generators in Blumlein configuration. These deliver pulse lengths in the range of several nanoseconds. Suspended cells are preferably treated in electroporation cuvettes, whereas cultured cells can be treated with a special electrode system in multi-well plates. The subsequent examination of the cells includes not only the usual cell and molecular biological assays but also the detection of electroporation using fluorescent dyes.



Intracellular cell-cell communication in cultured mouse skin fibroblasts detected with fluorescence-labelled antibodies: Connexin 43 (red), F-actin (green), and cell nuclei (blue)

Genetic engineering:

There is expertise and equipment for carrying out genetic engineering work at security levels S1 and S2. Thus, non-viral and adenoviral gene transfer systems can be produced. A therapeutic effect is achieved by transferring genes with the help of overexpression vectors or gene inhibitors (siRNA). These therapeutic genes can be used 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 (time-limited) effect in cell culture systems. In contrast, adenoviral vectors are currently the most efficient gene transfer system because they have the highest *in vivo* transduction rates and express the gene product to be transferred for up to three months. In addition to extensive expertise in gene expression, methods such as quantitative real-time PCR and global microarray analysis are applied.

Cell culture and histology:

Expertise and equipment for performing histological analyses. Based on close cooperation with clinical partners, we are also able to conduct and support patient-oriented research. Thin tissue sections are prepared from excised tissue samples using a freezing microtome or microtome. This is followed by immunohistochemical or immunofluorescence staining. These histological techniques are also used for animal experiments that are carried out through collaborations.

Microscopy:

Fluorescence microscopy is used especially for the analysis of fluorescence-labelled tissue sections. A confocal laser scanning microscope is also available.
Atomic force microscopy (AFM) is used to image surfaces in a non-destructive manner and with high resolution – even on living cells – and to determine the mechanical properties of a sample. With this technique, elastic moduli can be determined.

Outlook:

The broad spectrum of methods opens up a wide range of topics from clinical to industrial research. Most of the existing methods and expertise can be excellently combined and supplemented. This results in a multitude of further investigation possibilities for research in the field of Plasma Life Science.

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Plasma Modelling

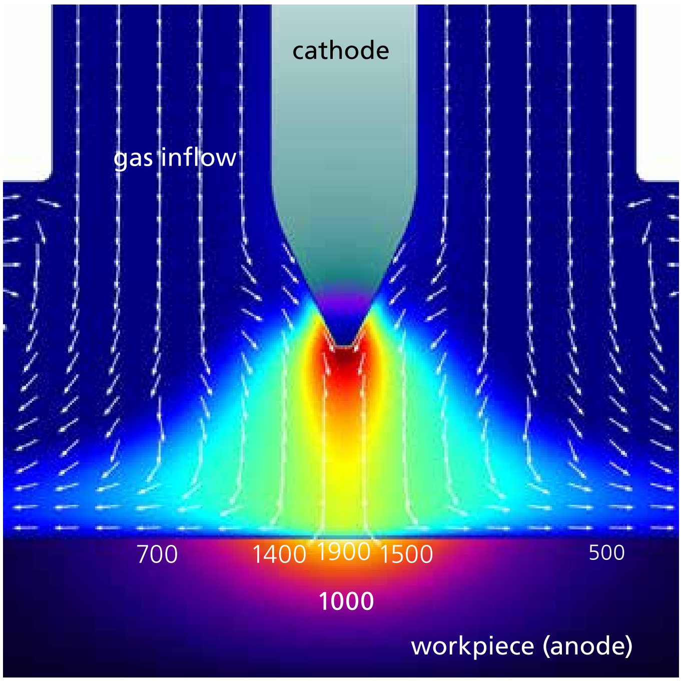
In the field of plasma research and technology, the modelling of plasma sources and reactors is becoming increasingly important. On the basis of systematic parameter studies, the model calculations and simulations make it possible to optimise technological plasmas in a targeted manner as well as to develop new applications. This can reduce the practical implementation of costly and time-consuming experiments. The model calculations and simulations also make it possible to determine parameters that are experimentally inaccessible or difficult to access and analyse.

At the INP, models with scientific and technological utilisation potential are developed and applied. These are primarily non-thermal plasmas at atmospheric and low pressure. The spectrum of models ranges from the description of individual plasma effects to the complete modelling of plasma sources and processes. The current focus is on plasma sources for the modification of surfaces and for energy and environmental applications, plasma processes for the deposition of organosilicon films, the decomposition or conversion of pollutants, and the controlled generation of reactive species for plasma-medical applications as well as arc plasmas for welding, cutting, and switching. Furthermore, solutions for the management of research data will be developed. These will enable the publication of these data according to the FAIR principles (i.e. findable, accessible, interoperable, and reusable) and thus the improved re-use of research results in the field of plasma technology.

The modelling of the plasmas requires different partial steps. This includes the development of an adequate plasma model, the formulation of hydrodynamic or kinetic equations for the plasma species, the preparation of corresponding equations for the electric and magnetic field, and the derivation of suitable conditions at the boundaries of the solution area. Furthermore, the problem-specific atomic data must be researched and evaluated.

To solve the resulting system of ordinary and partial differential equations, suitable numerical methods are to be developed or adapted. Depending on the problem, commercial codes or open source programs are used. Following the systematic determination of solutions for the specific plasma application, the results are to be interpreted in terms of content, adequately visualised and, among other things, published in refereed journals.

The complexity of the overall description of plasma applications necessitates that sub-problems (e.g. the plasma-chemical modelling of reactive plasmas, the determination of the electric field configuration, the kinetic description of the electrons and ions, and the treatment of radiation transport) are sometimes treated separately. However, a self-consistent modelling of plasma sources and reactors is primarily pursued in order to adequately capture the various interactions of the sub-problems and to achieve predictive results.



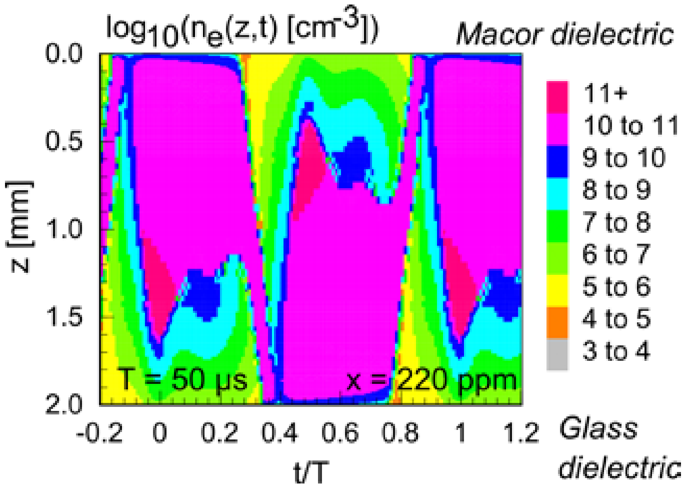
Self-consistent modelling of temperature distribution and gas flow in a tungsten inert gas welding arc at a current of 200 A

The numerical treatment and theoretical analysis of the non-thermal, weakly ionised plasmas is performed using methods developed at the INP as well as using commercial modelling software such as Comsol Multiphysics® and open source programs such as FEniCS. The problem-specifically adapted numerical methods of INP are characterised by high efficiency, stability, and accuracy. They were verified by means of benchmark comparisons.

The model calculations and plasma simulations are carried out on modern clusters, the availability of which is essential for the numerical treatment of complex, multidimensional problems. The investigations are usually carried out within the framework of funded projects at the INP. For the most part, they take place in close connection with experimental work and in cooperation with national and international partners from research institutions and industry.

In the medium term, the research of the department will focus on the realistic description and analysis of the properties and behaviour of scientifically and technologically relevant low-temperature plasmas. In addition to the currently investigated plasma applications in the research programmes Materials and Surfaces, Plasma Chemical Processes, Welding and Switching, and Decontamination plasmas for plasma-medical applications will increasingly be investigated.

The investigations of these low-temperature plasmas serve in particular for the physical understanding and quantitative determination of (i) the temporal and spatial change of the particle densities of individual plasma components, (ii) the energy dissipation due to collision and radiation processes, (iii) the particle and energy transport processes in the plasma, (iv) the electric and magnetic fields occurring in the plasma, and (v) the interaction of individual species with walls, electrodes, and organic components as well as the plasma-liquid interaction.



Spatio-temporal development of the electron density in a large-area dielectric barrier Ar discharge with the addition of x = 220 ppm hexamethyldisiloxane for the deposition of silicon-organic films

A further focus of the department in the medium term will be on research data management. Standards for the storage and documentation of research data from the various research methods are to be developed step by step. These standards are intended to form the basis for interdisciplinary networking and the semantic linking of data and meta-data by means of a subject-specific ontology and a knowledge graph based on it. This will allow linking to external data at a fine-grained level. In addition, the use of the interdisciplinary plasma technology data platform of INP (INPTDAT; https://www.inptdat.de) for publishing digital research data will be intensified.

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Plasma Surface Technology

In the Department of Plasma Surface Technology, plasma-assisted processes for the modification of surfaces are investigated. These are used in various industries. Plasma processes play a central role in the targeted adjustment of surface properties both in the high-tech sector (e.g. in automotive engineering, aerospace industry, photonics, microelectronics, tool coating, textile industry, and plastics processing) and in the life science sector (e.g. in biomedical engineering for implants, medical instruments, biosensors, and the food industry).

Plasma processes in surface technology cover the spectrum from structured material removal (e.g. etching or fine cleaning) to the adjustment of the interface properties (e.g. to control the bondability or printability) to the production of thin functional films with applications for protection against corrosion, heat, or mechanical abrasion as well as for the coating of optics. In this way, plasma technology can be used to create new material surfaces with specific functions.

The expertise includes:

Interface engineering
- Modification of metal, ceramic, glass, and plastic surfaces
- Antimicrobial surfaces
- Hydrophilic/hydrophobic surfaces
- Biocompatible surfaces
- Cell-adhesive/anti-adhesive surfaces
- Textile treatment

Process development for the deposition of thin films:
- Hard materials
- Wear protection
- Corrosion and oxidation protection
- Optical films
- Scratch-resistant surfaces
- Photocatalytically active surfaces

Surface finish
- Plasma fine cleaning
- Plasma-based polishing, deburring, and cleaning of conductive materials
- Polishing of 3D-printed metal components

Technological equipment

Various plasma processes are used under low and normal pressure conditions; these are continually being further developed. Both laboratory and industrial scale plants are available for this purpose:

- 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 vapour deposition (PECVD)
- Surface modification by means of atmospheric pressure discharges (DBD, plasma jet)

Industrial system for the thermal atmospheric pressure plasma spray process for producing functional films

Surface analysis is one of specialities of the INP. The existing spectrum of diagnostic procedures, the expertise in operation, and the methodology for evaluating the measurement data is continually being expanded and improved.

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, bond, and structure

- 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

Investigation of mechanical properties

- Microindenter
- Nanoindenter
- Taber test

Determination of contact angle and surface energy

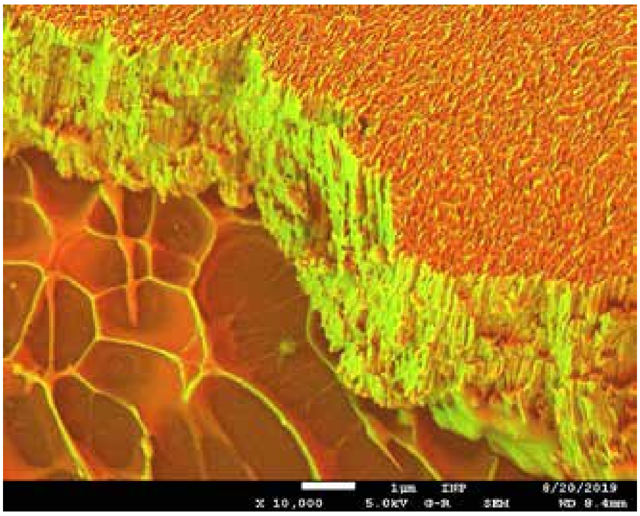
- Contact angle measurement devices

Determination of the optical properties

- UV–VIS spectrophotometry
- Optical ellipsometry

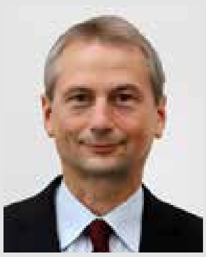
The following topics are the subject of current developments in the application of plasma surface technology processes at the INP:

- Surface finish of 3D-printed work pieces
- Plasma smoothing of conductive surfaces
- Development of modern plasma processes for film deposition at normal pressure
- Coating of plastics by means of
- High rate deposition process (plasma spraying)
- Use of plasma-based methods for process control and regulation



Electron microscopic image of the edge of a metal film (approx. 2.5 µm) produced at the INP for laser ablation (cooperation with the MPI für Plasmaphysik)

CONTACT



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Plasma Process Technology

The expertise of the Department of Plasma Process Technology on the topics of plasma-assisted vacuum processes for generating catalytically active films and plasma-chemical material conversion was deepened and expanded.
The vacuum-based methods are focused on the synthesis of nanoporous metallic, metal oxide thin films. In particular, patented processes such as PVD (physical vapour deposition), magnetron sputtering, and plasma ion assisted deposition are used. Only by combining these coatings with chemical or electrochemical leaching processes it is possible to produce highly porous metal films that have high electrocatalytic activities in relation to their mass per unit area. Complementary electrochemical and surface analytical characterisation methods are available. In particular, a method for the investigation of gas diffusion electrodes in a half-cell arrangement was introduced. This allows measurements under conditions that are much closer to the conditions in the fuel cells and electrolysers than conventional methods. The main applications are in electrochemical storage as well as the conversion of electricity from renewable energy sources. The focus here is on increasing the resource efficiency of electrode materials.
PECVD (Plasma Enhanced Chemical Vapour Deposition) processes are available for the immobilisation of molecularly defined compounds on solid surfaces such as carbon, metal or non-metal oxides. Using various plasma polymer films such as polyallyl alcohol, polyallylamine or a-C:H films, it is possible to partially encapsulate catalytically active molecules on surfaces without impeding the chemical exchange processes. This represents a process for the heterogenisation of typically homogeneous catalysts. These catalysts can be recycled using cost-effective separation methods.

Expertise on plasma catalytic processes using CO_2 as raw material was also acquired. Heatable plasma sources in the form of dielectric barrier discharges (DBD) and the corresponding gas phase analysis are available for the synthesis of CO from CO_2.
For the treatment of biomass, established processes include a combination of a plasma source (spark discharge or microwave discharge) and an ultrasonic source with a common field of action.

Experimental equipment

Plasma technology PVD, PECVD:

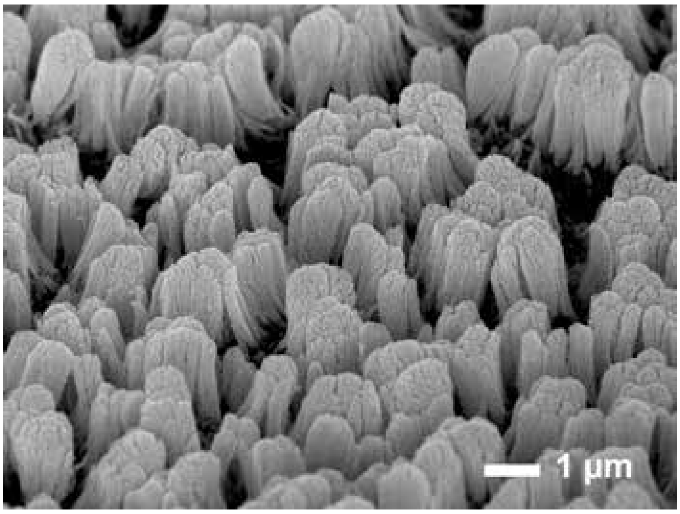
- Six vacuum recipients with 2 and 3 plasma sources for the deposition of
  - Metal oxide films e.g. semiconducting films such as TiO_2, WO_3
  - Carbon-metal nanohybrid films e.g.: C-Pt
  - Metal-metal nanohybrid films e.g.: Pt-Co
  - Metal/metal oxide polymer composite films e.g: CO_2O_3-HMDSO plasma poylmer
  - Metal-polymer complex films, e.g.: Co-polypyrrole
- PIAD vacuum coating system, M 900

Plasma technology powder modification:

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

Plasma technology synthesis of nanoparticles:

- Plasmas in liquids, pulsed discharges e.g.: Synthesis of nanoscaled, graphene supported metal oxide particles



Porous platinum film on a gas diffusion layer

Characterisation of nanostructure, morphology, crystal structure, molecular structure, and porosity:

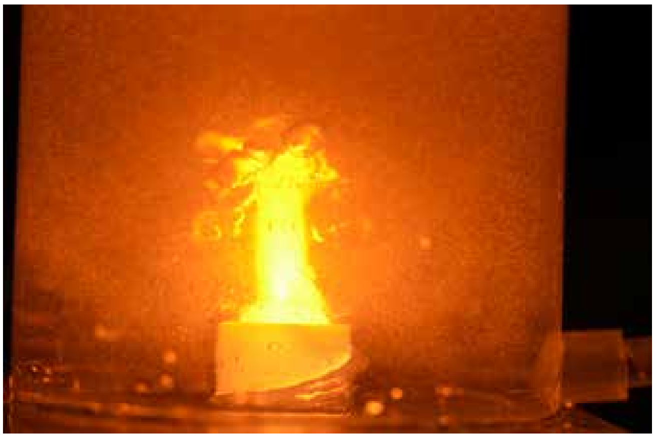
- Keyence digital microscope: 2D and 3D images with up to 1000x magnification
- BET sorption measurement, Quantachrome NOVA2000: Determination of the specific surface of solids by nitrogen adsorption.
- FTIR spectrometer: Bruker VERTEX 70v: digital FTIR vacuum spectrometer for measurements in the MIR (8000 to 350 cm^{-1}) and FIR (600 to 50 cm^{-1}) range
- MasterSizer 2000 from Malvern Instruments: Measurement of particle size distribution of powders in the range from 20 nm to 2 mm
- Bruker D8 Advance X-ray diffractometer with high resolution LYNXEYE detector: X-ray diffraction (XRD) on polycrystalline films and powders to identify crystal phases and crystallite sizing. X-ray reflectometry (XRR) to determine film thickness and roughness. Rietveld analysis
- Scanning electron microscopy/EDX, Joel (Germany) GmbH, plus cross section polisher, IB-09010CP, Joel (Germany) GmbH: Cross-section polishing unit for producing mirror-smooth surfaces, which cannot be polished mechanically

Characterisation of optical, electrochemical, and photochemical properties:

- PerkinElmer Lambda 850 UV/Vis spectrophotometer with L6020322 150 mm integrating sphere; measurement of transmission, scattering, 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 films
- Im6e Potentiostat, Zahner GmbH, Electrochemical characterisation
- PCS Photoelectrochemical Photo Current Spectra System, Zahner GmbH
- CIMPS Fast Light Intensity Transient System, Zahner GmbH, photoelectrochemical measurement
- COLT Coating and Laminate Tester, Zahner GmbH, AC-DC-AC tests on coatings and laminates
- Nordic Electrochemistry potentiostat with positive feedback for iR compensation at high currents for GDE measurements

Outlook on future focuses:

- Development and stabilisation of methods for the production of highly porous catalyst films for electrocatalysis
- plasma chemical conversion of substances in gases and liquids for the use of CO_2
- Combination of plasma and electrocatalysis for the synthesis of chemical storage of electrical energy
- Combination of plasma and ultrasound for the disintegration of biological substrates



Microwave plasma (2.45 GHz) in water at atmospheric pressure

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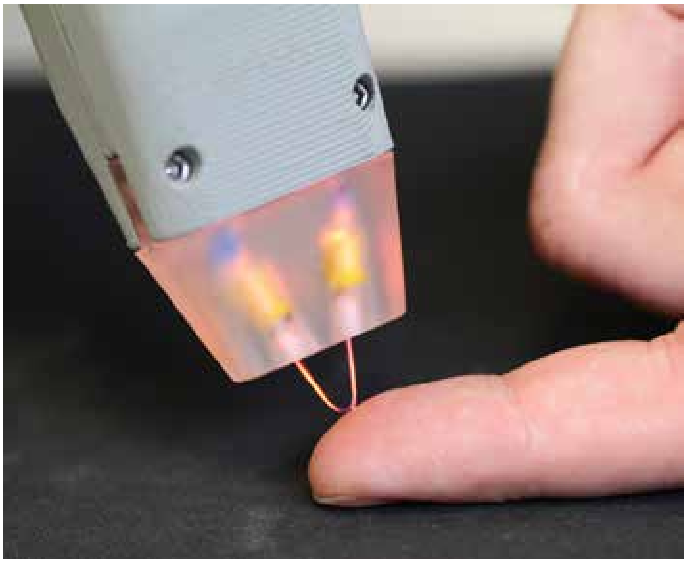
Plasma Sources

The development and characterization of atmospheric-pressure plasmas is a core competence of INP. Depending on the specific application and customer requirements, different methods and systems are developed to support the work of the research programmes. This development is accompanied by an intensive characterisation of the plasma sources. This enables us not only to understand and control existing plasma processes but also to design new processes and optimise existing technologies.

Special emphasis is placed on activities to research and develop integrated atmospheric-pressure plasma systems as new production tools or for use in environmental technology and healthcare. For this work, the INP has special laboratories in which the plasma sources can be designed, manufactured, and plasma-diagnostically characterised. The activities of the Plasma Sources Department are also supported by an interdepartmental research infrastructure. In addition to the most modern methods of plasma diagnostics, microbiological and cell biological laboratories, plasma chemical analysis, various environmental monitoring systems, and diagnostics for surface and material properties can be used.



In the ONKOTHER-H project, the V-Jet developed at the INP is being investigated for its suitability in the inactivation of cancer cells.

Especially the proximity to the biological laboratories enables the Department of Plasma Sources to evaluate biological effects of new plasma source concepts efficiently and practically without having to accept long waiting times and distances. This is particularly useful when developing new decontamination procedures.

The research infrastructure is complemented by rapid prototyping technologies such as 3D printing, stereolithography, and laser cutting. This allows the fast and flexible development of novel plasma source concepts, which enables us to answer feasibility inquiries from project partners from industry and research in a clear and timely manner.

In plasma source development, we focus on three areas: Medical plasma sources, technical plasma sources, and pulsed power.

a) Medical plasma sources:
The core task of the Plasma Sources Department in the development of plasma sources in the medical or medical-related environment is the design and construction of problem-adapted plasma sources for plasma medical experiments as well as for disinfection and decontamination. This includes the programming of control software as well as the technical support of clinical partners.
Like all products used in medicine, the development of medical plasma sources is subject to increased requirements. We meet this demand by taking legal requirements (e.g. standards for electrical safety) into account right from the development stage. In addition, analyses of parameters relevant for approval such as irradiance and leakage currents are carried out.

An example of a plasma source used for plasma medical research is the V-Jet shown in the figure.

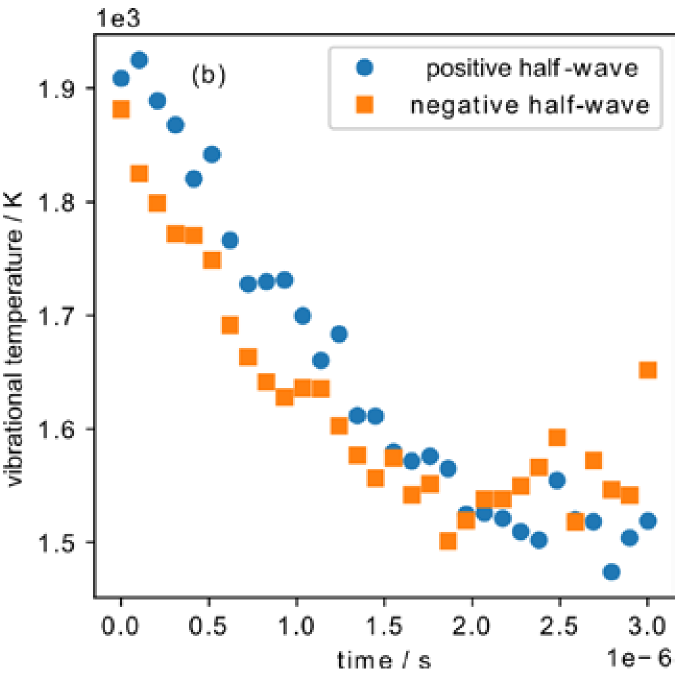
b) Technical plasma sources
Technical plasma sources are those devices not used in a medical environment. These include plasma sources for indoor air hygiene, exhaust gas treatment and plasma chemical synthesis. Furthermore, plasma arrangements for the degradation of contaminations in water (e.g. pharmaceutical residues) are set up and investigated. In addition to these established topics, the Department of Plasma Sources also helps meet source requirements for the relatively new research field of plasma agriculture. Here, plasma sources that can be used to treat seeds, plants, and liquids are particularly in demand.

c) Pulsed power technology
The design and construction of pulsed high voltage power supplies for pulsed plasmas and pulsed electric fields (Bioelectrics) is another focus of the Department of Plasma Sources. The pulsed power technology is particularly well suited for waste water treatment and material synthesis. Due to a precise measuring technique we are able to reliably characterise even the most sophisticated high voltage signals.

The department also possesses broad expertise in analysis and production processes. In gas phase analysis, highly sensitive methods (including FTIR, GC, GC/MS, FID) are used to detect plasma-generated reactive species (e.g. H_2O_2, NO_x, O_3) down to the ppb range. We also carry out investigations of optical emission spectroscopy from the infra-red to the VUV spectral range and can investigate extremely fast processes down to the ns range using imaging techniques (ICCD camera, framing camera). An application example for the combination of imaging and spectroscopy is determining the phase-resolved vibration temperature in a dielectric barrier discharge (see figure). In addition to extensive electrical measurement technology, we also have expertise in the characterisation and simulation of gas phase chemistry.

The expertise in the field of liquid analysis ranges from the detection of chemical substances using HPLC to the analysis and characterisation of plasma-treated liquids.

Manufacturing technologies:
This includes 3D manufacturing of metal objects and Fused Deposition Modelling. Using the latter, several materials can sometimes be printed simultaneously. Furthermore, 3D objects can be generated with very fine resolution using SLA printers in stereolithography. A fast and reproducible cutting of planar geometries from the materials stainless steel (<3 mm) as well as quartz and plexiglass is achieved with laser cutter technology (CO_2 & Nd:YAG).



Phase resolved determination of the vibration temperature of nitrogen in a dielectric barrier discharge (DBE).

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Plasma Radiation Techniques

The department is dedicated to the experimental analysis of technological plasmas in various applications of energy technology (high current, high voltage, switchgear technology) and process engineering (welding and cutting technology). Electrical and optical – especially spectroscopic – diagnostic methods are used for quantitative analysis.

Current research programmes on investigations of vacuum arcs in circuit breakers, of arcs in arresters and DC contactors, of arcs in welding technology, of wall-stabilised arc plasmas at high pressures, and of plasma phenomena in high-voltage insulation systems.

The further development of methods of high-speed kinematography coupled with optical emission and absorption spectroscopy serves to improve the physical properties of the plasmas under investigation in practical model arrangements and laboratory experiments. The focus is on increasing the sensitivity and spatial resolution of optical methods, extending their applicability to cold boundary layers and surfaces, the detection and characterisation of spatially asymmetric plasmas with high dynamics, robustness to interference in real applications, and flexible and mobile use.

In addition to the quantification of local properties in the arc, the determination of surface temperatures and other properties (e.g. electrodes in various arc applications) is also of interest. Based on the expertise in laboratory diagnostics, application-specific non-invasive sensor and control systems are developed. In addition to state-of-the-art diagnostic systems, the department has access to the latest equipment in welding, high-current, and high-voltage technology as well as vacuum technology.

A view into the arc laboratory: Synthetic test circuit (right in picture, the INP's own development), vacuum chamber with pump system and drive (left in picture).

Technological equipment

Arc research laboratory
- Synthetic test circuit for switching devices with maximum current up to 80 kA and return voltage up to 42 kV
- Impulse current generator with variable current form (AC variable frequency 16–1000 Hz, pulsed DC, lightning current pulse)
- Vacuum chamber for investigations on high current vacuum arcs
- Electrical and optical metrology

Welding Arc laboratory
- Test stands with fixed torch holder and flexible movement of test work pieces under the torch, including gas supply, extraction, and radiation protection
- Power sources from various manufacturers as well as a freely programmable source
- Electrical and optical metrology

High voltage laboratory
- HV generator for AC voltage up to 100 kV, DC voltage up to 130 kV, pulsed voltage up to 135 kV
- Partial discharge diagnostics (conventional according to IEC 60270, frequency response analysis, acoustic sensors, UHF sensors, measurements of the dielectric response, resistance meters

Continuous current laboratory

- Continuous current test stands (max. 3000 A)
- Climate laboratory with climate chamber for cooling and heating cycles (–70 to 180 °C) and heating cabinets (250 °C)
- Thermographic camera
- Thermal probes
- Resistance measuring devices (nΩ to μΩ)

Photometric laboratory

- Test stands with suitable power generators to simulate realistic operation
- Measuring stations for optical examinations of small-scale and low-light objects (micro arcs, partial discharges, lightning current discharges)
- Optical calibration sources

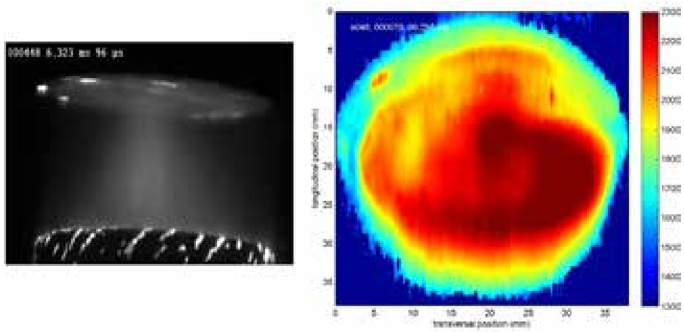
Equipment for optical measurements

The following equipment for optical measurements is available to all laboratories:

- Mobile and stationary measuring stations for imaging optical emission spectroscopy and optical absorption spectroscopy
- High and very high speed camera technology
- Technology for thermography/pyrometry
- X-ray computer tomography for non-destructive diagnostics of electrodes or material samples

Future focuses

- Acquisition of expertise in quantitative diagnostics in the field of high and very high pressure arcs
- Adaptation of quantitative diagnostic methods for the characterisation of plasma-wall and plasma-electrode interaction for application on cold surface boundary layers
- Extension of temperature measurements from ambient temperature to the melting point for studies of the cooling dynamics of electrical contacts and analysis of their energy balance
- Implementation of a drive system with variable parameters (opening and closing speed, contact force, time-distance curve) for studies on switch-on and switch-off processes under realistic working conditions
- Connection to the topic of DC technology/energy storage by setting up and commissioning a high-voltage laboratory in the Centre for Life Science, including HVDC generator, high-performance battery (5 kV/1000 A) and suitable measurement technology
- Construction of a measuring station with plasma torch for studies on plasma separation processes for waste disposal and material conversion
- Direct measurements of particle densities using spectroscopic and photometric methods and determination of the gas temperature for quantitative investigations to characterise thermal non-equilibrium plasmas



Snapshot of a vacuum arc (left) and temperature distribution of the upper electrode (anode) at 10 kA (right).

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Management Support - Research Management

Modern research institutions require professional research management. Since 2007, the INP Greifswald has had its own department, the Management Support, for this purpose. The Management Support advises the Board of Directors, the heads of the research divisions, and the research programme managers in matters of research strategy and patent law. Its task is to advise and support INP scientists in the acquisition of third-party funds. It provides information on new funding guidelines and is jointly responsible for the preparation of proposals. The Management Support also supports the transfer of technology and knowledge as well as process management. In addition to implementing its own projects, the Management Support is also responsible for communication.

Research funding

About half of the total budget of the INP is made up of competitive third-party funding from federal and state ministries, the German Research Foundation, the Leibniz Association, the European Union, and industry. The Management Support supports the scientific departments in the acquisition of these third-party funds. Its staff members research suitable funding programmes at the local, national, and European level and internally check the eligibility of the scientists' project ideas. The Management Support actively support the scientists during the preparation and submission of project applications: They provide support in the creation and formulation of project ideas, the preparation of resource, time, and work plans, overall budget planning, and their integration into the (funding) political context. The Management Support acts from the point of view of the funding authorities and thus contributes to increasing the quality of the INP project applications.

Project coordination

The Management Support supports the institution in the implementation of large-scale projects by providing project coordinators. These have a steering and coordinating function and represent the link between the scientists and the administration. Its project-accompanying tasks include preparing decision papers for budget planning and controlling project resources and the project schedule. Its staff members are also responsible for presenting the projects externally and organising board meetings and scientific workshops. They ensure a regular exchange between employees and support the establishment and expansion of communication networks for partners (research institutions and industrial companies). The coordinators are also responsible for communication with and reporting to the project promoters. The research work in the projects is thus optimally supported.

Public relations work

TheManagement Support is also responsible for external communication and organises all event and marketing activities of the INP. In the area of public relations, it communicates information (press releases), maintains media contacts, looks after visitors, organises events, designs the Institute's own print and online presence (e.g. advertising material and the website), and communicates via the Institute's social media channels.

INP Greifswald regularly organises national and international conferences, symposia, workshops, and networking events. Here, the department provides support in planning, organisation, and implementation. For external events (e.g. industrial trade fairs), we design the Institute's presence and provide support in preparing the events.

Our work in the graphics sector includes the conception, design, and production of in-house print and digital media. From corporate design, flyers, brochures, and animations for external presentation to assistance with illustrations and graphics for publications of our scientists, we offer a wide range of support.

The tasks also include targeted communication with groups in science, business, politics, and society as well as student marketing.

Industrial property rights

The goal of INP is to convert its research results into usable products and/or technologies and to offer them to industry as early as possible or transfer them to INP spin-offs. The Management Support therefore includes the position of a patent manager. The patent manager manages the inventions and industrial property rights of the INP (especially patents, utility models, and trademarks). She/he works closely with the INP inventors and external patent law firms. The patent manager also chairs the monthly meetings of the Patent Board, which consists of the Chairman of the Board and Scientific Director, the Chief Financial Director, and the head of the Management Support department. Within the framework of its meetings, the Patent Board takes the individual strategic decisions on industrial property rights for the INP.

Knowledge and technology transfer

The Institute's motto – FROM IDEA TO PROTOTYPE – outlines not only the statutory mission to conduct application-oriented fundamental research but also the use of the research results.

INP Greifswald conducts public research funding projects in order to increase knowledge for socially relevant topics. The Institute continually publishes the results of these projects in peer-reviewed journals, at national and international conferences, and at events for the general public.

For application-relevant topics of economic interest, the INP Greifswald makes its knowledge available as a customer solution. These mostly bilateral industrial projects help our economic partners to benefit directly from the latest findings of research work at the INP.

For its own technology transfer, INP was the first Leibniz institute ever to spin off its own company, neoplas GmbH (www.neoplas.eu). This serves as the second part of the three-step model developed at the institute. According to the motto "From prototype to product", pilot customers are included in the development work.

If certain recycling activities have proven to be economically viable, these may result in further spin-offs. Knowledge that is economically exploitable and is not initially to be offered as a customer solution can thus be developed to market maturity in a new spin-off: "From product to market".

Administration & Infrastructure

The "Administration & Infrastructure" department at the INP provides organisational support for the scientific departments and groups. It essentially organises the smooth running of operations. Both the administration and infrastructure are streamlined.

The Institute's Administration/Infrastructure department comprises the five subject areas of human resources, finance/controlling (including procurement, accounting, system and external funding management, travel expenses and electronic laboratory), infrastructure, and IT. The subject area Infrastructure consists of the mechanical and glass-blowing workshops and also looks after the Institute's building technology and all construction measures. For data processing, INP maintains and further develops a data network and maintains the connection of the INP network to external networks.

To ensure occupational health and safety requirements as well as safety standards, expert commissioners (e.g. hazardous substances, fire protection, electrical safety, radiation protection, data protection, laser protection, and biological safety) are appointed. Activities are coordinated by the Security Officer, who has authority to issue directives on behalf of the Board of Directors.

APPLICATION LABORATORIES

Laboratory for Surface Diagnostics

The properties of materials and the interaction of materials with the environment are primarily determined by the surface quality. With the help of plasma technology it is possible to specifically modify almost any surface property. In this way, novel material surfaces with special functions can be produced. Surface analysis is one of the specialist fields of the INP. The existing spectrum of diagnostics, the expertise in operation, and the methodology for evaluating the measurement data is continually being expanded and improved.

Analysis of topography and morphology

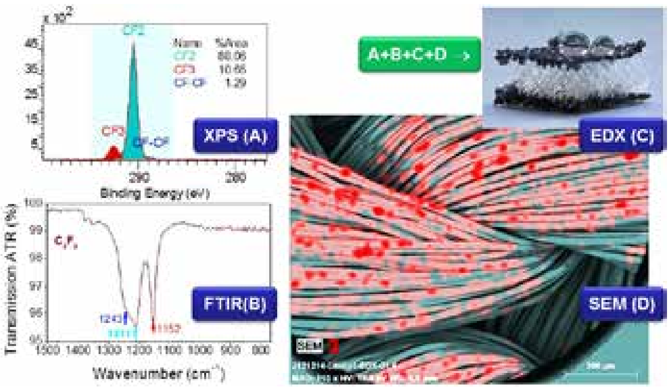
- High resolution scanning electron microscopy (HR SEM)
- Scanning transmission electron microscopy (STEM)
- Atomic force microscopy (AFM)
- Profilometry
- White-light interferometry
- Light microscopy with 3D function

Determination of chemical composition, bond, and structure

- 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



Correlated investigations (A+B+C+D) enable application-oriented optimisation of the properties of plasma-treated samples. The sample surface was coated with a fluorocarbon plasma polymer.

Investigation of mechanical properties

- Microindenter
- Nanoindenter

Determination of contact angle and surface energy

- Contact angle measuring instruments

Determination of the surface charge of solids

- Zeta potential measuring device

Determination of the optical properties

- UV–VIS spectrophotometry
- Optical ellipsometry

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Arc Research Laboratory

The arc laboratory primarily serves application-oriented research to increase the reliability and service life of switching devices. To this end, experiments are carried out on arcs in a vacuum or at normal pressure. Specific arrangements make it possible to simulate the behaviour of the arcs and the load of the electrodes in low, medium or high voltage switches at different pulse lengths (e.g. by means of suitable electrode arrangements in vacuum chambers or the use of consumable nozzles). At the same time, the set-ups can be used for fundamental research on high-current arcs and their interaction with electrodes, walls, and external magnetic fields. A unique selling point of the laboratory is the coupling of specific optical diagnostics for physical analysis of the arcs. Optical emission or absorption spectroscopy, for example, allows the measurement of temperatures and species densities in the arc and from this, the determination of all relevant plasma properties.
High-speed analyses are used to study the structure and dynamics. The surface temperature of electrodes is also accessible.

The laboratory set-up includes in particular:

- Test stand for the operation of high current arcs by means of impulse current generators with the following parameters (peak values): sinusoidal current pulse of 80 kA/5 ms, 40 kA/10 ms, or 25 kA/20 ms, square wave pulses up to 10 kA/2 ms or 2kA/10 ms, and flexible electrode arrangement, including actuator for electrode separation
- Vacuum chamber including electrode holder and one-sided actuator as well as extensive accesses for probe measurements and optical diagnostics
- Electrical measurement technology and optical sensor technology (photodiodes) for recording the time series of current, voltage, and radiation signals in selected spectral ranges, including specific evaluation methods
- 0.5 or 0.75 m spectrographs with intensified CCD cameras (single images with exposure times in the time range from ns to ms) for optical emission spectroscopy
- High-speed camera technology for up to 70,000 frames/s for arc observation including spectrally selective filters (narrow-band MIF, edge filters, polarising filters) and special optics for parallel observation with two different filters (double image optics) and one camera
- High-speed camera (4 independent images within e.g. 5 ns with exposure times from 3 ns) and streak camera (time resolution <1 ns, one spatial dimension) for the observation of ignition processes in the ns range

Impulse current generator and vacuum chamber in the arc laboratory

CONTACT

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Welding Arc laboratory

Application-oriented research activities focus on investigations of process safety, stability, and efficiency in arc welding. The focus is on the time-resolved and spatially resolved analysis of the arc, its attachment at the electrodes, the material transfer, and the weld pool. Plasma diagnostics allows the measurement of temperatures and species densities in the arc and from this, the determination of all relevant plasma properties. High-speed analyses are used to investigate the structure and dynamics of arcs and material transfer as well as ignition processes. The surface temperature of the weld pool, droplet depot and the droplets is also accessible.

Specially equipped laboratories for diagnostics of welding processes under realistic conditions of practical applications by means of modern measuring techniques are available for the examinations. These include, in particular:

- Test stands with fixed torch holder and flexible movement of test work pieces under the torch for optical analysis of the process from different angles
- Power sources from various manufacturers (including Fronius CMT advanced 4000R and EWM Phoenix 521 progress pulse coldarc) as well as a freely programmable source (TopCon Quadro)
- Electrical measurement technology and optical sensor technology (photodiodes) for recording the time series of current, voltage, and radiation signals in selected spectral ranges, including specific evaluation methods and spectrally high-resolution measurements of spectra in the spectral range from 300 nm to 900 nm with a spectral resolution of approx. 0.05 nm
- 0.5 or 0.75 m spectrographs with intensified CCD cameras (single images with exposure times in the time range from ns to ms) for optical emission spectroscopy, especially for temporally, spatially, and spectrally high-resolution measurements of spectra in the spectral range from 300 nm to 900 nm with a spectral resolution of approx. 0.05 nm
- High-speed camera (4 independent images within e.g. 5 ns with exposure times from 3 ns) and streak camera (time resolution 1 ns, one spatial dimension) for the observation of ignition processes in the ns range
- Thermography/pyrometry for the non-contact measurement of temperatures of surfaces and electrodes
- X-ray computer tomography for non-destructive diagnostics of electrodes or material samples

The diagnostic equipment (spectroscopy, high-speed camera and thermography) is also mobile and can be used for external measurements.

Set-up for carrying out welding tests with fixed torch position and moving work piece combined with equipment for imaging spectroscopy and high-speed kinematography.

CONTACT

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Voltage/Continuous Current Laboratory

The application-oriented research activities focus on investigations to increase the service life and reliability of electrotechnical equipment with special consideration of environmental protection and energy efficiency.

The following topics are currently being worked on in the laboratories for high voltage and high current technology (at the joint chair of the University of Rostock):

- Electrical contacts and connections: Long-term stability (ageing behaviour), thermal design (modelling), and design (material and surfaces)
- Partial discharge diagnostics and analysis of electrical equipment and components
- Investigations into the ageing behaviour of insulating materials under extreme conditions
- Arc plasmas: Experiments, modelling, and diagnostics of switching arcs

High-current and high-voltage laboratories with modern measuring equipment are available for the tests

- High-voltage laboratory with digital measuring system and measuring equipment for partial discharges (basic noise level <1 pC), for AC voltage up to 100 kV, DC voltage up to 130 kV, and pulse voltage of 135 kV
- Partial discharge diagnostics with partial discharge analysis system (IEC 60270, UHF, acoustics), resistance measurement system (35 TÙ, test voltage 10 kV), dielectric response analyser (200V, 100 ìHz to 5 kHz)

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

- Climate laboratory with climate chamber for cooling and heating cycles (–70 to 180 °C) and heating cabinets (250 °C)
- High-current laboratory with continuous-current test benches (max. 3000 A), temperature measurement using thermal sensors, and infra-red camera technology

CONTACT

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Microbiological Laboratory

Workplace in the microbiological laboratory

The microbiological laboratory at INP has security level 2 in accordance with Section 44 of the German Protection against Infection Act (IfSG) and thus permits activities with pathogens in accordance with Section 49 IfSG and Section 13 of the Biological Substances Ordinance. Current research covers phyto-pathogenic and human pathogens, including antibiotic-resistant micro-organisms in risk groups 1 and 2. (Section 49 IfSG and § 13 BioStoffV (Ordinance on Biological Agents), 2000/54/EG and 2010/32/EU)

The micro-organisms used are:

- Bacillus atrophaeus endospores
- Candida albicans
- Enterococcus faecium
- Escherichia coli
- Geobacillus stearothermophilus endospores
- Listeria innocua
- Listeria monocytogenes
- Micrococcus luteus
- Pectobacterium carotovorum
- Pseudomonas aeruginosa
- Pseudomonas fluorescens
- Pseudomonas marginalis
- Salmonella enteritidis
- Salmonella typhimurium
- Staphylococcus aureus

The institute also cooperates with accredited and certified testing laboratories in the field of hygiene and participates in round robin tests within research projects.

In the microbiological laboratory, projects for application-oriented fundaamental research as well as contract research are carried out in collaboration with industrial cooperation partners. The focus is on investigating the antimicrobial effectiveness of atmospheric-pressure plasma sources. A unique feature is the specific and individual adaptation of the test conditions and specimens to the requirements of the plasma sources and devices to be tested according to the later application. The focus is on the testing of antimicrobial plasma effects for the treatment of sensitive materials, medical devices, food, and waste water as well as the investigation of plasma sources for the treatment of liquids. The inactivation of airborne micro-organisms is also being researched.

The spectrum of microbiological methods includes growth experiments, antimicrobial sensitivity tests, and microscopic investigations. A spiral plate system and a spectrophotometer are available for determining the live cell count or optical density. Appropriate nutrient media and incubators (heating cabinets) can be used to cultivate micro-organisms. In addition, aseptic performance of the tests can be guaranteed at safety workbenches.

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Laboratory for High-Frequency Engineering

The Laboratory for High-Frequency Engineering is concerned with the provision, optimisation, and development of methods and systems of high-frequency engineering. Their use ranges from the small signal range for diagnostic applications to the large signal range for driving microwave plasma sources.

The focus is currently on the following systems:

- (frequency-resolved) microwave interferometry in power controlled and free radiating systems up to 150 GHz
  - Electron density determination: 10^{12}–10^{22} m^{-3}, $\Delta t < 1$ µs
  - Determination of permittivity and permeability
- Development and implementation of beam shaping elements (mirrors and lenses) to adapt 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 electron density determination
- Adaptation and optimisation of methods of digital signal processing
- Development of microwave power components for the manipulation of scattering parameters
  - Phase shifters
  - Adaptation networks
  - Mode coupler
  - Barrier-free access to reactors
- Development of microwave plasma sources
  - Mini-MIP (powers < 100 W)
  - Plexc (powers < 1500 W)
  - PLexc2 (powers < 4500 W)

The development work in the listed fields of activity is supported by numerical tools such as Matlab©, Comsol Multiphysics©, and CST Microwave Studio©. The results obtained can be validated using network analysis systems with a measurement range up to 50 GHz.

Electron density measurement with a 50 GHz interferometer at a low-pressure plasma discharge

CONTACT

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Laboratory for AOM Laser and Industrial Sensor Technology

The laboratory for AOM Laser and Industrial Sensor Technology forms the basis for the construction and provision of AOM laser systems or the development and application of measurement methods based on them. The AOM laser is used as a basic component of the EasyLAAS measuring system in laser absorption measurement technology for determining particle densities, electron densities, temperature, and pressure in plasmas as well as an industrial particle density and pressure sensor for technical gases.
A further topic is the development of non-laser based sensors. These include an NO_2 sensor used for process control at plasma sources and the MiniMip plasma ssource, which can be used as a chemical sensor.

The focus is currently on the following systems:

- MiniMip: Plasma source used together with gas chromatograph and optical spectrometer; detection limit of mercury: 10^{-13} g (100 fg)
- NO_2 sensor: high dynamic range: 10–10000 ppm
- EasyLaas/AOM laser: Measuring speeds up to 250 kHz (scans per second); electronic tuning range up to 11 nm (1700 GHz, 56 cm^{-1}); systems at various wavelengths:

  - System 455 nm: Particle density measurement up to 10^7 particles/cm³ (at absorption length of 2 mm)
  - System 1370 nm: non-contact pressure measurement on beverage bottles; measuring interval (including evaluation) up to 100 µs; accuracy 50 mbar @ 100 ms averaging time
  - System 770 nm: Measurement of oxygen atom densities (5S0, 777 nm) on kINPen in the range of 10^9 1/cm³ with focal multipath arrangement; measurement of excited argon densities in welding arcs
  - System 770 nm: absolute distance interferometry in the sub-micron range
  - System 810 nm + 790 nm: Measurement of argon particle density (10^{10} 1/cm³), gas temperature (1000 K) and electron density (10^{20} 1/m³) at various plasma sources

EasyLAAS system for laser absorption measurements

The data acquisition is supplemented by signal processing with evaluation algorithms specially adapted to the measuring task so that very low detection limits can be achieved and that the existing potential for real-time capability (thanks to the extremely high scanning speeds of the AOM laser) can be utilised.

CONTACT

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Laboratory for Plasma-Bio-Process Technology

The Laboratory for Plasma-Bio-Process Technology provides the facilities for providing, optimising, and developing methods, processes and systems for treating biological materials with plasma. Depending on requirements, scales from laboratory to pilot plant scale are realised both internally and externally. One focus is on microwave-excited plasma sources.

The focus is currently on the following systems:

Auxiliary Decontamination Unit (ADU)
Two-stage self-igniting atmospheric microwave excited plasma torch for RNS process gas generation (plasma processed air – PPA) with process control for operation of peripheral devices, capacity: 100 slm.

General Purpose Unit (GRP)
Two-stage self-igniting atmospheric microwave excited plasma torch for RNS process gas generation (plasma processed air – PPA) with process control for operation under industrial conditions, capacity 100 slm

Units for the production of plasma processed water (PPW)
Total capacity: 2000 l

Various peripheral devices for dry and wet treatment of bulk goods, fruit and vegetables, and meat products in batches of up to 200 kg

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

Measurement technology:
Mass spectrometry
Fourier transform infra-red spectroscopy
Fluorescence microscopy
Concentration measurement of nitrogen dioxide
Humidity measurement with high time resolution

Process plant for treating products in Reusable Plastic Containers (RPC)

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We see ourselves as the leading institution in plasma research and technology in Germany, comprehensively combining basic research and applications.
As part of the Leibniz Association, the INP is a non-university research facility with focus on application-oriented basic research in the field of low temperature plasma physics.

GOOD SCIENTIFIC PRACTICE

We deliver top performances in the areas of science and technology due to good scientific practice.
Our research is carried out in accordance to the rules for the safeguarding of good scientific practice of the Leibniz Association and the German Research Foundation (DFG). This includes, amongst other things, the consistent orientation towards the current standard of international research and technology, the continuous advancement of the scientific methods in use, an in-depth working method; including the constant questioning of one's own results; the recognition of the scientific work of each individual and the promotion of broad cooperation.

STRATEGY

Strategically, the institute aims at the realisation of long-term goals and sustainable results.
In the pursuit of offering the best possible working conditions for its employees, the institute secures a creative working environment and seeks to open up new perspectives. High scientific standards and future-oriented topics of relevance for all of society, on an international scale, are central to our work. Which, based on a well-founded overall strategy, allows us to help shape trends in politics, economics and research.

EQUAL OPPORTUNITY

We offer fair and balanced life and access opportunities for all.
The INP actively promotes equal opportunities for women and men, as well as for people with special needs, whilst creating a family friendly working environment. Equal opportunities, nondiscrimination, family-friendliness and the reconciling of work and family life are an integral part of the institute's culture, on all organisational levels. We see it as our responsibility to live along the lines of these standards and to secure them.

COMMUNICATION AND SPIRIT

We regard each other with openness, fairness and tolerance.
In dealing with each other, as well as our partners, we treat everyone with esteem, respecting cultural diversity. Interdisciplinary and internal cooperation is the foundation of our success. We encourage our employees to take responsibility and to co-decide within their scope of work, as defined by the matrix structure.

PROMOTION OF YOUNG TALENT

We support junior staff on all organisational levels of the institute and beyond.
In the competition for the best scientific minds, junior staff development is one of our main concerns, in all fields of activity. Our application oriented basic research sparks young researchers' interest in topics of relevance to society as a whole. We facilitate concrete experience in research, as well as in cooperation with industry partners. To us, junior staff development comprises all qualification stages – from school, over university and apprenticeship, to profession.

INTERNATIONALISATION

We operate nationally and internationally with success.
From Greifswald, we cooperate with globally recognised research institutes. We encourage our scientists to seize international exchange opportunities and support fellowships for international researchers at our institute. The active participation in the shaping of the European research activities is one of our focal points.

TRANSFER OF RESEARCH SERVICES

The results of our research are socially and economically exploitable, by turning them into concrete applications.
This includes the publication of scientific results and their transfer into products and services.

Reconciliation of Family and Professional Life

High-quality results can be achieved at a research institute only with highly motivated employees. They must be given the best possible encouragement in their professional and personal development as well as substantial support in reconciling professional and private life. The Leibniz Institute for Plasma Science and Technology (INP) is therefore actively committed to gender equality. This is an integral part of INP's philosophy and is anchored in the statutes and guidelines of the institute. This issue receives considerable attention from the Institute's management in terms of strategic planning for equality and the implementation of individual activities. In the past two years, the proportion of women has risen further to almost 40%.

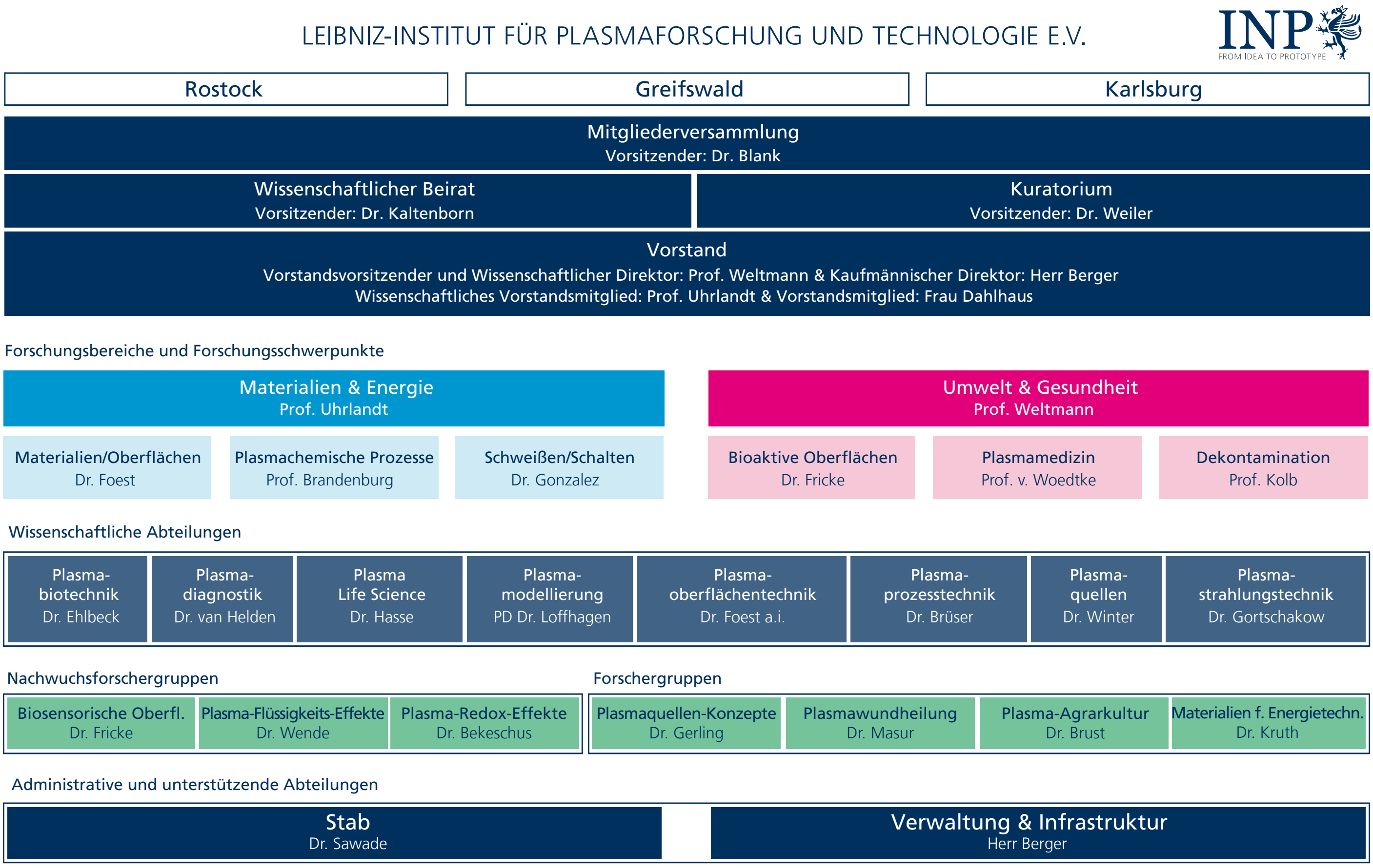
Because good commitment to gender equality is more than quotas and laws, we create specific family-friendly working conditions. In this way, we inspire the best researchers in their field and bind them and their scientific potential to the INP in the long term. The services offered to our employees range from individual working time and location agreements to a parent-child room that can be used in the case of childcare shortages.

Our employees from a wide range of nations and have diverse career paths. We are committed to equal opportunities and non-discrimination at all levels of the institute. We support our employees with customised personal development opportunities, which are discussed in regular meetings.

We have already received the TOTAL E-QUALITY award twice for our equal opportunities work. In 2020, we will apply for a further extension and hope to once again convince the jury with our equal opportunities work.

TOTAL E-QUALITY Deutschland e.V. recognises the successful and sustainable commitment of organisations and companies to equal opportunities in the workplace. The award was developed with the help of the Federal Ministry of Education and Research (BMBF) and the European Union and is given for exemplary action in the sense of personnel management oriented towards equal opportunities.

Recognition for successfully implemented equal opportunities awarded by TOTAL E-QUALITY Deutschland e.V.



Board of Trustees

The Board of Trustees is the supervisory body of INP to which the members of the state and federal government also send their representatives.

It decides on all essential scientific, economic, and organizational issues of the INP.

Members (2019)

Scientific Advisory Council

The Scientific Advisory Council is the advisory body of INP. The members active in the research field of the institute include internationally renowned scientists from university and non-university research as well as industry. The Scientific Advisory Council advises the Board of Trustees and the Board of Directors on all important scientific and organisational issues, in particular on long-term research planning.

Members (as of 2019)

General Assembly

The General Assembly is the highest decision-making body of the INP. It elects the Board of Trustees, decides on amendments to the statutes, receives the report of the Board of Directors on the general situation of INP, and approves the activities of the Board of Directors.

Members (as of 2019)

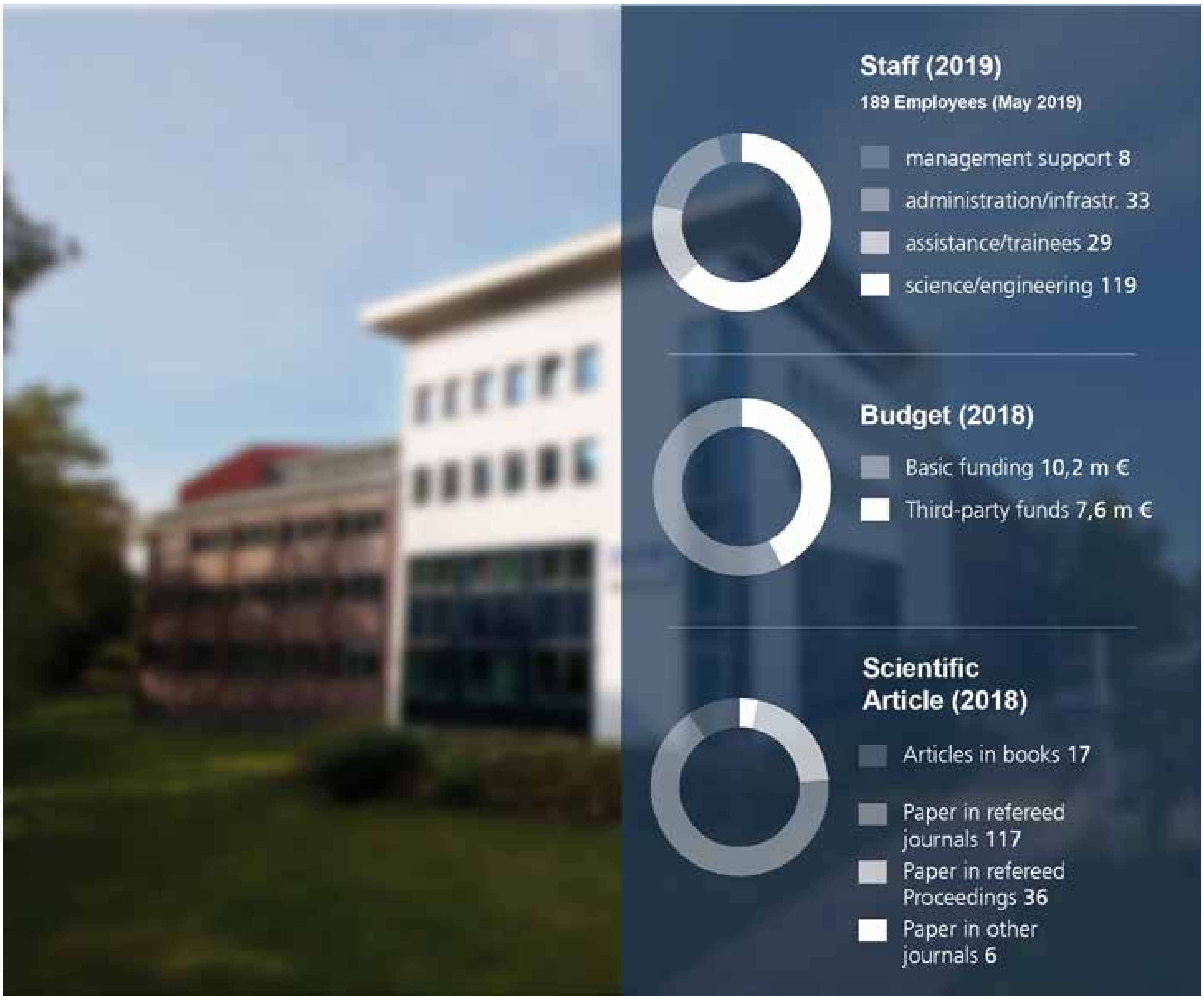
Facts and figures

Budget:

The total budget amounted to €17.5 million in reporting year 2018 and €19.6 million in reporting year 2019. Personnel expenses were € 10.6 million (2018) and € 10.6 million (2019), and operating expenses were € 4.1 million (2018) and € 3.96 million (2019). € 2.9 million was invested in INP equipment in 2018 and € 4.97 million in 2019.

Personnel:

As of May 2019, the INP Greifswald has a total of 189 employees, 119 of whom work in scientific and technical areas and 70 in scientific support. Just over 39% of employees are women.



Memberships of the INP

- RWI - Regionale Wirtschaftsinitiative Ost Mecklenburg-Vorpommern e.V. (Regional Economic Initiative East Mecklenburg-Vorpommern)
- Deutscher Bibliotheksverband e.V. (German Library Association)
- idw - Informationsdienst Wissenschaft (Information Service Science)
- German Water Partnership e. V.
- HYPOS Hydrogen Power Storage & Solutions East Germany e.V.
- Nationales Zentrum für Plasmamedizin e.V. (National Centre for Plasma Medicine)
- Europäische Forschungsgesellschaft Dünne Schichten e.V. (European Research Society for Thin Films)
- enviMV e.V. – Environmental Technology Network from Mecklenburg-Vorpommern
- Deutsche Lichttechnische Gesellschaft e.V. (German Lighting Technology Society)
- Deutsche Physikalische Gesellschaft e.V. (German Physical Society)
- Forschungsvereinigung Schweißen und verwandte Verfahren e. V. des DVS (Research Association on Welding and Allied Processes of the DVS)
- DECHEMA - Gesellschaft für Chemische Technik und Biotechnologie e.V. (Society for Chemical Engineering and Biotechnology)
- IUTA - Institut für Energie- und Umwelttechnik e. V. (Institute for Energy and Environmental Technology)
- Carbon Concrete Composite e.V.
- BdP - Bundesverband deutscher Pressesprecher e.V. (Federal Association of German Press Speakers)
- INPLAS - Kompetenznetz Industrielle Plasma-Oberflächentechnik e.V. (Competence Network Industrial Plasma Surface Technology)
- BVMW - Bundesverband mittelständische Wirtschaft, Unternehmerverband Deutschlands e.V. (Federal Association of Small and Medium-Sized Enterprises, German Employers' Association)
- WTI - Wasserstofftechnologie-Initiative e.V. (Hydrogen Technology Initiative)
- Hydrogen Europe Research Association (formerly N.ERGHY)
- Greifswald University Club e.V.
- GFaI - Gesellschaft zur Förderung angewandter Informatik e.V. (Society for the Promotion of Applied Computer Science)
- Initiative Chronische Wunden e.V. (Chronic Wounds Initiative)
- Forum MedTech Pharma e.V. (MedTech Pharma Forum)
- Deutsche Gesellschaft für Plasmatechnologie e.V. (German Society for Plasma Technology)

COOPERATIONS

- AJ Drexel Plasma Institute
  Philadelphia, USA
- Alexandru Ioan Cuza University of Iasi
  Iași, Romania
- Alpes Lasers SA
  St Blaize, Schweiz
- Brno University of Technology
  Brno, Czech Republic
- C³ Carbon Concrete Composite e. V.
  Dresden
- CentraleSupélec, University Paris-Saclay
  Gif-sur-Yvette, Frankreich
- Centre for Mathematical Plasma-Astrophysics
  Leuven, Belgien
- Centre Suisse d'Electronique et de Microtechnique
  Neuchâtel, Schweiz
- Centrum Wiskunde & Informatica
  Amsterdam, Niederlande
- Charité Berlin
  Berlin
- Chongqing University
  Chongqing, China
- Christian-Albrechts-Universität zu Kiel
  Kiel
- Comenius University in Bratislava
  Bratislava, Slovakia
- Costa Rica institute of Technology
  Cartago, Costa Rica
- CSIRO Manufacturing
  Lindfield, Australia
- Deutsches Textilforschungszentrum Nord-West gGmbH
  Krefeld
- DLR - German Aerospace Center
  Köln
- DLR-Institute of Networked Energy Systems
  Oldenburg
- Dutch Institute for Fundamental Energy Research (DIFFER)
  Eindhoven, The Netherlands
- EFDS - European Society of Thin Films
  Dresden
- EMPA - swiss federal laboratories for material science and technology
  Dübendorf, Schweiz
- Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik (FBH)
  Berlin
- Forschungsverbund Mecklenburg-Vorpommern e.V.
  Rostock
- Fraunhofer Institute for Applied Optics and Precision Engineering IOF
  Jena
- Fraunhofer Institute for Electronic Nano Systems
  Chemnitz
- Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM
  Bremen
- Fraunhofer Institute for Material and Beam Technology IWS
  Dresden
- Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology FEP
  Dresden
- Fraunhofer Institute for Surface Engineering and Thin Films IST, Braunschweig
- Fraunhofer Institute for Surface Engineering and Thin Films IST, DOC Dortmunder OberflächenCentrum GmbH
  Dortmund
- Fraunhofer-Research Institution for Large Structures in Production Engineering IGP
  Rostock

- Fudan University
  Shanghai, China
- Groupe des Couches Minces (GCM) and Department of Engineering Physics, Polytechnique Montreal
  Montreal
- Helmholtz-Zentrum Rossendorf
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- Hochschule für Angewandte Wissenschaft und Kunst
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- Hochschule Neubrandenburg
  Neubrandenburg
- Hochschule Stralsund
  Stralsund
- Holon Institute of Technology
  Holon, Israel
- Hunan University
  Hunan Cheng, China
- INM – Leibniz Institute for New Materials
  Saabrücken
- Innovent e.V.,
  Jena
- INPLAS - Network of Competence Industrial Plasma Surface Technology
  Braunschweig
- Institut für Energietechnik, Energieverfahrenstechnik und Umwandlungstechniken regenerativer Energien (EVUR)
  Berlin
- Institut für Werkzeugmaschinen und Fabrikbetrieb
  TU Berlin
  Berlin
- Institute for Solid State Physics and Optics, Wigner Research Centre for Physics
  Budapest, Hungary
- Institute of High Current Electronics
  Tomsk, Russia
- Institute of Plasma Physics of the Czech Academy of Science
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- 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
- Justus-Liebig Universität Gießen
  Gießen
- Karlsruhe Institute of Technology
  Karlsruhe
- Kaunas University of Technology
  Kaunas, Lithuania
- Klinikum Karlsburg
  Karlsburg
- KTH Stockholm
  Stockholm, Schweden
- Laboratoire Plasma et Conversion d'Énergie
  Toulouse, France
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  Rostock
- Leibniz Institute for Catalysis (LIKAT)
  Rostock
- Leibniz Institute for Crystal Growth
  Berlin
- Leibniz Institute for Farm Animal Biology (FBN)
  Dummerstorf
- Leibniz Institute of Photonic Technology (IPHT)
  Jena
- Lithuanian Energy Institute
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- Masaryk University
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- Max-Planck-Institut für Eisenforschung GmbH
  Düsseldorf
- Menlo Systems GmbH
  Planegg
- Nagoya University
  Japan
- National Institute for Laser, Plasma and Radiation Physics
  Bucharest, Romania
- neoplas GmbH
  Greifswald
- Nicolaus Copernicus University
  Torun, Poland
- North Carolina State University
  Raleigh, USA
- Old Dominion University Norfolk
  Virginia, USA
- Paul-Drude-Institut für Festkörperelektronik (PDI)
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- PBRC, Kwangwoon University
  Seoul, Korea
- Peking University
  Peking China
- Plasma Advanced Research Center, University Iasi
  Romania
- PlasmaMedic LTD
  Israel
- Preparatory Institute of Engineering Studies of Monastir
  Tunesien
- PTB Braunschweig
  Braunschweig
- Queensland University of Technology
  Brisbane, Australia
- Research Center Borstel - Leibniz Lung Center
  Sülfeld
- Riga Technical University,
  Lettland
- Rübig GmbH & Co KG
  Wels, Österreich
- Ruhr-Universität Bochum
  Bochum
- RWTH Aachen University
  Aachen
- São Paulo State University (UNESP)
  São Paulo, Brasilien
- Schweißtechnische Lehr- und Versuchsanstalt Rostock (SLV)
  Rostock
- Sirona Dental Systems GmbH
  Bensheim
- St. Petersburg State University,
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- St.Petersburg Polytechnic University
  St. Petersburg, Russland
- Stadtwerke Netzgesellschaft mbH
  Rostock
- Szewalski Institute of Fluid Flow Machinery
  Gdansk, Poland
- Technical University of Denmark
  Roskilde, Denmark
- Technical University of Eindhoven,
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- Technische Universität Bergakademie Freiberg
  Freiberg
- Technische Universität Berlin
  Berlin
- Technische Universität Braunschweig
  Braunschweig

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- Technische Universität Ilmenau
Ilmenau
- Technological University Dublin, College of Sciences and Health, School of Food Science and Environmental Health
Dublin, Ireland
- TH Brandenburg
Brandenburg an der Havel
- The hydrogen and fuel cell center ZBT GmbH
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Sao Paulo, Brazil
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Rostock
- Universität zu Lübeck
Lübeck
- Universitätsklinikum des Saarlandes
Homburg
- Universitätsklinikum Erlangen, Strahlen-Immunbiologie
Erlangen
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Orléans, Frankreich
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- University of Buenos Aires,
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- University of Cambridge,
Cambridge, UK
- University of Greifswald
Greifswald
- University of Greifswald, University Medicine
Greifswald
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Madeira, Portugal
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- University of Oxford
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- University of York

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  Szczecin, Poland
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  gGmbH
  Neubrandenburg

INDIVIDUAL CONTRIBUTIONS TO EDITED VOLUMES 2018

1. Bekeschus, S.; Pouvesle, J.-M.; Fridman, A.; Miller, V.: **Cancer Immunology.** In: Metelmann, H.-R.; von Woedtke, T.; Weltmann, K.-D. (eds.), Comprehensive Clinical Plasma Medicine. Springer, Cham (2018) pp. 409-419; DOI:10.1007/978-3-319-67627-2_24

2. Gerling, T.; Helmke, A.; Weltmann; K.-D.: **Relevant Plasma Parameters for Certification.** In: Metelmann, H.-R.; von Woedtke, T.; Weltmann, K.-D. (eds.), Comprehensive Clinical Plasma Medicine. Springer, Cham (2018) pp. 43-70; DOI:10.1007/978-3-319-67627-2_3

3. Hahn, V.; Brandenburg, R.; von Woedtke, T.: DIN SPEC 91315: **A First Attempt to Implement Mandatory Test Protocols for the Characterization of Plasma Medical Devices.** In: Metelmann, H.-R.; von Woedtke, T.; Weltmann, K.-D. (eds.), Comprehensive Clinical Plasma Medicine. Springer, Cham (2018) pp. 511-516; DOI:10.1007/978-3-319-67627-2_35

4. Helmke, A.; Gerling, T.; Weltmann, K.-D.: **Plasma Sources for Biomedical Applications.** . In: Metelmann, H.-R.; von Woedtke, T.; Weltmann, K.-D. (eds.), Comprehensive Clinical Plasma Medicine. Springer, Cham (2018) pp. 23-41; DOI:10.1007/978-3-319-67627-2_2

5. Hilker, L.; von Woedtke, T.; Titze, R.; Weltmann, K.-D.; Motz, W.; Wollert, H.-G.: **The Use of Cold Atmospheric Pressure Plasma (CAP) in Cardiac Surgery.** In: Metelmann, H.-R.; von Woedtke, T.; Weltmann, K.-D. (eds.), Comprehensive Clinical Plasma Medicine. Springer, Cham (2018) pp. 201-211; DOI:10.1007/978-3-319-67627-2_12

6. Kramer, A.; Schauer, F.; Papke, R.; Bekeschus, S.: **Plasma Application for Hygienic Purposes in Medicine, Industry, and Biotechnology: Update 2017.** In: Metelmann, H.-R.; von Woedtke, T.; Weltmann, K.-D. (eds), Comprehensive Clinical Plasma Medicine. Springer, Cham (2018) pp. 253-281; DOI:10.1007/978-3-319-67627-2_14

7. Masur, K.; Bekeschus, S.: **Perspectives in Immunology of Wound Healing.** In: Metelmann, H.-R.; von Woedtke, T.; Weltmann, K.-D. (eds.), Comprehensive Clinical Plasma Medicine. Springer, Cham (2018) pp. 401-408; DOI:10.1007/978-3-319-67627-2_23

8. Metelmann, H.-R.; Hammes, S.; Hartwig, K.; von Woedtke, T.; Chien, T. T. T.; Rana, A.: **Safe and Effective Plasma Treatment by Structured Education.** In: Metelmann, H.-R.; von Woedtke, T.; Weltmann, K.-D. (eds.), Comprehensive Clinical Plasma Medicine. Springer, Cham (2018) pp. 467-472; DOI:10.1007/978-3-319-67627-2_30

9. Partecke, L. I.; Bekeschus, S.; Liedtke, K. R.: **Perspectives in General Surgery.** In: Metelmann, H.-R.; von Woedtke, T.; Weltmann, K.-D. (eds), Comprehensive Clinical Plasma Medicine. Springer, Cham (2018) pp. 347-354; DOI:10.1007/978-3-319-67627-2_20

10. Seebauer, C.; Metelmann, H.-R.; Witzke, K.; Pouvesle, J.-M.: **Palliative Treatment of Head and Neck Cancer.** In: Metelmann, H.-R.; von Woedtke, T.; Weltmann, K.-D. (eds.), Comprehensive Clinical Plasma Medicine. Springer, Cham (2018) pp. 185-195; DOI:10.1007/978-3-319-67627-2_10

11. von Woedtke, T.; Schmidt, A.; Bekeschus, S.; Wende, K.: **Introduction to Plasma Medicine.** In: Metelmann, H.-R.; von Woedtke, T.; Weltmann, K.-D. (eds.), Comprehensive Clinical Plasma Medicine. Springer, Cham (2018) pp. 3-21; DOI:10.1007/978-3-319-67627-2_1

12. Wende, K.; Schmidt, A.; Bekeschus, S.: **Safety Aspects of Non-Thermal Plasmas.** In: Metelmann, H.-R.; von Woedtke, T.; Weltmann, K.-D. (eds.), Comprehensive Clinical Plasma Medicine. Springer, Cham (2018) pp. 83-109; DOI:10.1007/978-3-319-67627-2_5

INDIVIDUAL CONTRIBUTIONS TO EDITED VOLUMES 2019

1. An, S.; Fricke, K.; Riemer, H.; Petersen, M.; Paschke, H.; Quade, A.; Ihrke, R.; Weltmann, K.-D.; Fröhlich, M.: **Vorbehandlung und Reinigung von Werkzeugoberflächen durch plasmaelektrolytisches Polieren zur Verbesserung der Haftung von Verschleißschutzschichten.** In: Horn, K.: (ed.), Atmosphärische Plasmen. Anwendungen - Entwicklungen - Anlagen, Technologie-Spezial zum 10-jährigen Jubiläum des Anwenderkreis Atmosphärendruckplasma (ak-adp), Jena, MEOX Projektmanagement GbR, 2019, ISBN: 978-3-00-063646-2

2. Kewitz, T.; Testrich, H.; Gonzalez, D.; Gortschakow, S.; Fricke, K.; Fröhlich, M.; Weltmann, K.-D.: **Atmosphärendruck-Plasmaspritzen in der Hochspannungstechnik - thermische und elektrische Isolierschichten aus Al2O3.** In: Horn, K.: (ed.), Atmosphärische Plasmen. Anwendungen - Entwicklungen - Anlagen, Technologie-Spezial zum 10-jährigen Jubiläum des Anwenderkreis Atmosphärendruckplasma (ak-adp), Jena, MEOX Projektmanagement GbR, 2019, ISBN: 978-3-00-063646-2

3. von Woedtke, T.; Schmidt, A.; Bekeschus, S.; Wende, K.; Masur, K.; Gerling, T.; Hasse, S.; Hahn, V.; Steuer, A.; Semenov, I.; Winter, J.; Weltmann, K.-D.: Plasmamedizin: **innovative therapeutische Anwendungen von kaltem Atmosphärendruckplasma.** In: Horn, K.: (ed.), Atmosphärische Plasmen. Anwendungen - Entwicklungen - Anlagen, Technologie-Spezial zum 10-jährigen Jubiläum des Anwenderkreis Atmosphärendruckplasma (ak-adp), Jena, MEOX Projektmanagement GbR, 2019, ISBN: 978-3-00-063646-2

4. Emmert, S; Boeckmann, L; Fischer, T; Bernhardt, T; Borchardt, T; Viöl, W; Wahl, P; Wandke, D; Metelmann, H; Masur, K; Bekeschus, S; von Woedtke, T.; Weltmann, K.-D.: **Plasmamedizin für Hauterkrankungen: Wunden und Tumoren.** In: Horn, K.: (ed.), Atmosphärische Plasmen. Anwendungen - Entwicklungen - Anlagen, Technologie-Spezial zum 10-jährigen Jubiläum des Anwenderkreis Atmosphärendruckplasma (ak-adp), Jena, MEOX Projektmanagement GbR, 2019, ISBN: 978-3-00-063646-2

EDITORSHIP OF EDITED VOLUMES 2018

1. Metelmann, H.-R.; von Woedtke, T.; Weltmann, K.-D.: **Comprehensive Clinical Plasma Medicine.** Springer, Cham (2018); DOI:10.1007/978-3-319-67627-2

2. Weidmann, B.; von Woedtke, T.: **Das menschliche Maß.** Evangelische Verlagsanstalt Leipzig (2018); ISBN 978-3-374-05685-9

EDITORSHIP OF EDITED VOLUMES 2019

1. Weidmann, B.; von Woedtke, T.: **Das menschliche Maß.** Evangelische Verlagsanstalt Leipzig, 2. Auflage (2019); ISBN 978-3-374-05685-9

ARTICLES IN PEER-REVIEWED JOURNALS 2018

1. Ahrens, P.; Zander, M.; Hasse, U.; Wulff, H.; Jeyabharathi, C.; Kruth, A.; Scholz, F.: **Electrochemical Formation of Gold Nanoparticles on Polycrystalline Gold Electrodes during Prolonged Potential Cycling.** ChemElectroChem 5 (2018) 943-957; DOI:10.1002/celc.201700745

2. Almansoori, A.; Masters, R.; Abrams, K.; Schäfer, J.; Gerling, T.; Majewski, C.; Rodenburg, C.: **Surface modification of the laser sintering standard powder polyamide 12 by plasma treatments.** Plasma Process. Polym. 15 (2018) 1800032; DOI:10.1002/ppap.201800032

3. Almuina-Villar, H.; Anca-Couce, A.; Lang, N.; Röpcke, J.; Behrendt, F.; Dieguez-Alonso, A.: **Laser-Based Spectroscopy Diagnosis and Detailed Numerical Models to Gain Understanding on the Slow Pyrolysis Behavior of Thermally Thick Wood Particles.** Chem. Eng. Trans. 65 (2018) 109-114; DOI:10.3303/CET1865019

4. Arndt, S.; Schmidt, A.; Karrer, S.; von Woedtke, T.: **Comparing two different plasma devices kINPen and Adtec SteriPlas regarding their molecular and cellular effects on wound healing.** Clin. Plasma Med. 9 (2018) 24-33; DOI:10.1016/j.cpme.2018.01.002

5. Arumugam, S.; Haba, Y.; Koerner, G.; Uhrlandt, D.; Paschen, M.: **Understanding partial discharges in low-power relay and silicone cable modified to suit high-voltage requirement of deep sea electrical system.** Int. Trans. Electr. Energ. Syst. 28 (2018) e2542; DOI:10.1002/etep.2542

6. Baeva, M.: **Application of the transferred matrix method to a unified evaluation of the cathodic electron emission.** AIP Adv. 8 (2018) 085322; DOI:10.1063/1.5041314

7. Baeva, M.; Hempel, F.; Baierl, H.; Trautvetter, T.; Foest, R.; Loffhagen, D.: **Two- and three-dimensional simulation analysis of microwave excited plasma for deposition applications: operation with argon at atmospheric pressure.** J. Phys. D: Appl. Phys. 51 (2018) 385202; DOI:10.1088/1361-6463/aad537

8. Bagheri, B.; Teunissen, J.; Ebert, U.; Becker, M. M.; Chen, S.; Ducasse, O.; Eichwald, O.; Loffhagen, D.; Luque, A.; Mihailova, D.; Plewa, J. M.; van Dijk, J.; Yousfi, M.: **Comparison of six simulation codes for positive streamers in air.** Plasma Sources Sci. Technol. 27 (2018) 95002; DOI:10.1088/1361-6595/aad768

9. Barillas, L.; Cubero-Sesin, J. M.; Vargas-Blanco, I.: **Hydroxyapatite Coatings on Polymers Using a Custom Low-Energy Plasma Spray System.** IEEE Trans. Plasma Sci. 46 (2018) 2420-2424; DOI:10.1109/TPS.2018.2810639

10. Barillas, L.; Testrich, H.; Cubero-Sesin, J. M.; Quade, A.; Vargas, I.; Polak, M.; Fricke, K.: **Bioactive Plasma Sprayed Coatings on Polymer Substrates Suitable for Orthopedic Applications: A Study With PEEK.** IEEE Trans. Radiat. Plasma Med. Sci. 2 (2018) 520-525; DOI:10.1109/TRPMS.2018.2832450

11. Bekeschus, S.; Brüggemeier, J.; Hackbarth, Ch.; Weltmann, K.-D.; von Woedtke, Th.; Partecke, L.-I.; van der Linde, J.: **The feed gas composition determines the degree of physical plasma-induced platelet activation for blood coagulation.** Plasma Sources Sci. Technol. 27 (2018) 034001; DOI:10.1088/1361-6595/aaaf0e

12. Bekeschus, S.; Clemen, R.; Metelmann, H.-R.: **Potentiating anti-tumor immunity with physical plasma.** Clin. Plasma Med. 12 (2018) 17-22; DOI:10.1016/j.cpme.2018.10.001

13. Bekeschus, S.; Freund, E.; Wende, K.; Gandhirajan, R. K.; Schmidt, A.: **Hmox1 Upregulation Is a Mutual Marker in Human Tumor Cells Exposed to Physical Plasma-Derived Oxidants.** Antioxidants 7 (2018) 151; DOI:10.3390/antiox7110151

14. Bekeschus, S.; Käding, A.; Schröder, T.; Wende, K.; Hackbarth, C.; Liedtke, K. R.; van der Linde, J.; von Woedtke, T.; Heidecke, C.-D.; Partecke, L.-I.: **Cold Physical Plasma-Treated Buffered Saline Solution as Effective Agent Against Pancreatic Cancer Cells.** Anticancer Agents Med. Chem. 18 (2018) 824-831; DOI:10.2174/1871520618666180507130243

15. Bekeschus, S.; Lackmann, J.-W.; Gümbel, D.; Napp, M.; Schmidt, A.; Wende, K.: **A Neutrophil Proteomic Signature in Surgical Trauma Wounds.** Int. J. Mol. Sci. 19 (2018) 761-784; DOI:10.3390/ijms19030761

16. Bekeschus, S.; Lin, A.; Fridman, A.; Wende, K.; Weltmann, K.-D.; Miller, V.: A Comparison of Floating-Electrode DBD and kINPen Jet: **Plasma Parameters to Achieve Similar Growth Reduction in Colon Cancer Cells Under Standardized Conditions.** Plasma Chem. Plasma Process. 38 (2018) 1-12; DOI:10.1007/s11090-017-9845-3

17. Bekeschus, S.; Mueller, A.; Miller, V.; Gaipl, U.; Weltmann, K.-D.: **Physical Plasma Elicits Immunogenic Cancer Cell Death and Mitochondrial Singlet Oxygen.** IEEE Trans. Radiat. Plasma Med. Sci. 2 (2018) 138-146; DOI:10.1109/TRPMS.2017.2766027

18. Bekeschus, S.; Schmidt, A.; Kramer, A.; Metelmann, H.-R.; Adler, F.; von Woedtke, T.; Niessner, F.; Weltmann, K.-D.; Wende, K.: **High throughput image cytometry micronucleus assay to investigate the presence or absence of mutagenic effects of cold physical plasma.** Environ. Mol. Mutagen. 59 (2018) 268-277; DOI:10.1002/em.22172

19. Bekeschus, S.; Scherwietes, L.; Freund, E.; Liedtke, K. R.; Hackbarth, C.; von Woedtke, T.; Partecke, L.-I.: **Plasma-treated medium tunes the inflammatory profile in murine bone marrow-derived macrophages.** Clin. Plasma Med. 11 (2018) 1-9; DOI:10.1016/j.cpme.2018.06.001

20. Bekeschus, S.; Wulf, C. P.; Eric Freund, E.; Koensgen, D.; Mustea, A.; Weltmann, K.-D.; Stope, M. B.: **Plasma Treatment of Ovarian Cancer Cells Mitigates Their Immuno-Modulatory Products Active on THP-1 Monocytes.** Plasma 1 (2018) 201-217; DOI:10.3390/plasma1010018

21. Bonitz, M.; Filinov, A.; Abraham, J. W.; Loffhagen, D.: **Extending first principle plasma-surface simulations to experimentally relevant scales.** Plasma Sources Sci. Technol. 27 (2018) 64005; DOI:10.1088/1361-6595/aaca75

22. Borges, A.; de Morais Gouva Lima, G.; Nishime, T.; Gontijo, A.; Kostov, K.; Koga-Ito, C.: **Amplitude-modulated cold atmospheric pressure plasma jet for treatment of oral candidiasis: In vivo study.** PLoS One 13 (2018) e0199832; DOI:10.1371/journal.pone.0199832

23. Brüning, A.; Hölker, F.; Franke, S.; Kleiner,W.; Kloas, W.: **Influence of light intensity and spectral composition of artificial light at night on melatonin rhythm and mRNA expression of gonadotropins in roach Rutilus rutilus.** Fish Physiol. Biochem. 44 (2018) 1-12; DOI:10.1007/s10695-017-0408-6

24. Burlacov, I.; Hamann, S.; Spies, H.-J.; Röpcke, J.; Biermann, H.: **On the influence of carbon contamination of reactor parts in active screen plasma nitrocarburizing processes.** J. Appl. Phys. 123 (2018) 233302; DOI:10.1063/1.5029228

25. Ceriani, E.; Marotta, E.; Schiorlin, M.; Ren, X.; Ceretta, C.; Gobbo, R.; Tampieri, F.; Paradisi, C.: **A versatile prototype plasma reactor for water treatment supporting different discharge regimes.** J. Phys. D: **Appl.** Phys. 51 (2018) 274001; DOI:10.1088/1361-6463/aac7cd

26. Che, Y.; Zhang, T.; Du, Y.; Amin, I.; Marschelke, C.; Jordan, R.: **"On Water" Surface-initiated Polymerization of Hydrophobic Monomers.** Angew. Chem. Int. Ed. 57 (2018) 16380-16384; DOI:10.1002/anie.201809100

27. Daeschlein, G.; Rutkowski, R.; Lutze, S.; von Podewils, S.; Sicher, C.; Wild, T.; Metelmann, H.-R.; von Woedkte, T.; Jünger, M.: **Hyperspectral imaging: innovative diagnostics to visualize hemodynamic effects of cold plasma in wound therapy.** Biomed. Eng. Biomed. Tech. 63 (2018) 603-608; DOI:10.1515/bmt-2017-0085

28. Dalke, A.; Burlacov, I.; Hamann, S.; Puth, A.; Spies, H.-J.; Röpcke, J.; Biermann, H.: **Plasma Nitrocarburizing of AISI 316L Austenitic Stainless Steel Applying a Carbon Active Screen: Status and Perspectives.** HTM J. Heat Treatm. Mater. 73 (2018) 246-257; DOI:10.3139/105.110363

29. Dosdall, R.; Preuß, F.; Hahn, V.; Schlüter, R.; Schauer, F.: **Decay of the water reed Phragmites communis caused by the white-rot fungus Phlebia tremellosa and the influence of some environmental factors.** Appl. Microbiol. Biotechnol. 102 (2018) 345-354; DOI:10.1007/s00253-017-8582-0

30. Eccard, J. A.; Scheffler, I.; Franke, S.; Hoffmann, J.: Off-grid: **solar powered LED illumination impacts epigeal arthropods.** Insect Conserv. Divers. 11 (2018) 600-607; DOI:10.1111/icad.12303

31. Ehlbeck, J.; Brust, H.; Wannicke, N.; Schnabel, U.; Andrasch, M.; Stachowiak, J.; Kolb, J.; Weltmann, K.-D.: **Potential of non-thermal plasma techniques for decontamination of wheat grains for agricultural use.** Cereal Technol. 4 (2018) 244-255; DOI:10.23789/1869-2303-2018-4-244

32. Engelowski, E.; Schneider, A.; Franke, M.; Xu, H.; Clemen, R.; Lang, A.; Baran, P.; Binsch, C.; Knebel, B.; Al-Hasani, H.; Moll, J. M.; Floß, D. M.; Lang, P. A.; Scheller, J.: **Synthetic cytokine receptors transmit biological signals using artificial ligands.** Nat. Commun. 9 (2018) 2034; DOI:10.1038/s41467-018-04454-8

33. Fiebrandt, M.; Lackmann, J.-W.; Stapelmann, K.: **From patent to product? 50 years of low-pressure plasma sterilization.** Plasma Process. Polym. 15 (2018) 1800139; DOI:10.1002/ppap.201800139

34. Filinov, A.; Bonitz, M.; Loffhagen, D.: **Microscopic modeling of gas-surface scattering. I. A combined molecular dynamics-rate equation approach.** Plasma Sources Sci. Technol. 27 (2018) 64003; DOI:10.1088/1361-6595/aac61e

35. Filinov, A.; Bonitz, M.; Loffhagen, D.: **Microscopic modeling of gas-surface scattering: II. Application to argon atom adsorption on a platinum (111) surface.** Plasma Sources Sci. Technol. 27 (2018) 64002; DOI:10.1088/1361-6595/aac620

36. Fleischmann, S.; Zeiger, M.; Quade, A.; Kruth, A.; Presser, V.: **Atomic Layer-Deposited Molybdenum Oxide/Carbon Nanotube Hybrid Electrodes: The Influence of Crystal Structure on Lithium-Ion Capacitor Performance.** ACS Appl. Mater. Interfaces 10 (2018) 18675-18684; DOI:10.1021/acsami.8b03233

37. Fridman, A.; Lin, A.; Miller, V.; Bekeschus, S.; Wende, K.; Weltmann, K.-D.: **The Plasma Treatment Unit: An Attempt to Standardize Cold Plasma Treatment for Defined Biological Effects.** Plasma Med. 8 (2018) 195-201; DOI:10.1615/PlasmaMed.2018026881

38. Fröhling, A.; Ehlbeck, J.; Schlüter, O.: **Impact of a Pilot-Scale Plasma-AssistedWashing Process on the Culturable Microbial Community Dynamics Related to Fresh-Cut Endive Lettuce.** Appl. Sci. 8 (2018) 2225; DOI:10.3390/app8112225

39. Gandhirajan, R. K.; Rödder, K.; Bodnar, Y.; Pasqual-Melo, G.; Emmert, S.; Griguer, C. E.; Weltmann, K.-D.; Bekeschus, S.: **Cytochrome C oxidase Inhibition and Cold Plasma-derived Oxidants Synergize in Melanoma Cell Death Induction.** Sci. Rep. 8 (2018) 12734; DOI:10.1038/s41598-018-31031-2

40. Gauter, S.; Fröhlich, M.; Kersten, H.: **Direct calorimetric measurements in a PBII and deposition (PBII&D) experiment with a HiPIMS plasma source.** Surf. Coat. Technol. 352 (2018) 663-670; DOI:10.1016/j.surfcoat.2018.03.094

41. Gianella, M.; Reuter, S.; Press, S. A.; Schmidt-Bleker, A.; van Helden J.; Ritchie, G. A.: **HO2 reaction kinetics in an atmospheric pressure plasma jet determined by cavity ring-down spectroscopy.** Plasma Sources Sci. Technol. 27 (2018) 95013; DOI:10.1088/1361-6595/aadf01

42. Gimsa, J.; Wysotzki, P.; Perutkova, Š.; Weihe, T.; Elter, P.; Marszałek, P.; Kralj-Iglič, V.; Müller, T.; Iglič, A.: **Spermidine-Induced Attraction of Like-Charged Surfaces Is Correlated with the pH-Dependent Spermidine Charge: Force Spectroscopy Characterization.** Langmuir 34 (2018) 2725-2733; DOI:10.1021/acs.langmuir.7b04199

43. Gonzalez, D.; Hopfeld, M.; Berger, F.; Schaaf, P.: **Investigation on Contact Resistance Behavior of Switching Contacts using a newly developed Model Switch.** IEEE Trans. Compon. Packag. Manuf. Technol. 8 (2018) 939-949; DOI: 10.1109/TCPMT.2018.2791839

44. Grabarczyk, P.; Winkler, P.; Delin, M.; Sappa, P.; Bekeschus, S.; Hildebrandt, P.; Przybylski, G.; Völker, U.; Hammer, E.; Schmidt, C.: **The N-Terminal CCHC Zinc Finger Motif Mediates Homodimerization of Transcription Factor BCL11B.** Mol. Cell. Biol. 38(5) (2018) e00368-17; DOI:10.1128/MCB.00368-17

45. Hahn, V.; Meister, M.; Hussy, S.; Cordes, A.; Enderle, G.; Saningong, A.; Schauer, F.: **Enhanced laccase-mediated transformation of diclofenac and flufenamic acid in the presence of bisphenol A and testing of an enzymatic membrane reactor.** AMB Expr. 8 (2018) 28; DOI:10.1186/s13568-018-0546-y

46. Handorf, O.; Weihe, T.; Bekeschus, S.; Graf, A. C.; Schnabel, U.; Riedel, K.; Ehlbeck, J.: **Nonthermal Plasma Jet Treatment Negatively Affects the Viability and Structure of Candida albicans SC5314 Biofilms.** Appl. Environ. Microbiol. 84 (2018) e01163-18; DOI:10.1128/AEM.01163-18

47. Hansen, L.; Schmidt-Bleker, A.; Bansemer, R.; Kersten, H.; Weltmann, K.-D.; Reuter, S.: **Influence of a liquid surface on the NOx production of a cold atmospheric pressure plasma jet.** J. Phys. D: **Appl.** Phys. 51 (2018) 474002; DOI:10.1088/1361-6463/aad6f0

48. Hegemann, D.; Indutnyi, I.; Zajckov, L.; Makhneva, E.; Farka, Z.; Ushenin, Y.; Vandenbossche, M.: **Stable, nanometer-thick oxygen-containing plasma polymer films suited for enhanced biosensing.** Plasma Process. Polym. 15 (2018) 1800090; DOI:10.1002/ppap.201800090

49. Hertel, M.; Schwill-Engelhardt, J.; Gerling, T.; Weltmann, K.-D.; Imiolczyk, S.; Hartwig, S.; Preissner, S.: **Antibacterial Efficacy of Plasma Jet, Dielectric Barrier Discharge, Chlorhexidine, and Silver Diamine Fluoride Varnishes in Caries Lesions.** Plasma Med. 8 (2018) 73-82; DOI:10.1615/PlasmaMed.2018024767

50. Hilker, L.; von Woedtke, T.; Masur, K.; Weltmann, K.-D.; Wollert, H.-G.: **Kaltplasma-Anwendungen bei Wundinfektionen mit Fremdkörperbeteiligung in der Herzchirurgie.** WUNDmanagement 12 (2018) 260-267

51. Höft, H.; Becker, M.; Kettlitz, M.: **Correlation of axial and radial breakdown dynamics in dielectric barrier discharges.** Plasma Sources Sci. Technol. 27 (2018) 03LT01; DOI:10.1088/1361-6595/aab39d

52. Höft, H.; Huiskamp, T.: **Direct comparison of pulsed spark discharges in air and water by synchronized electrical and optical diagnostics.** Eur. Phys. J. D 72 (2018) 217; DOI:10.1140/epjd/e2018-90505-0

53. Ignat, M.; Samoila, P.; Coromelci, C.; Sacarescu, L.; Asaftei, I.; Harabagiu, V.; Miron, C.: **Plasma generation in liquid as a new efficient synthesis approach of titania-ezinc ferrite nano(photo)catalyst.** C. R. Chim. 21 (2018) 310-317; DOI:10.1016/j.crci.2017.05.006

54. Jablonowski, H.; Santos Sousa, J.; Weltmann, K.-D.; Wende, K.; Reuter, S.: **Quantification of the ozone and singlet delta oxygen produced in gas and liquid phases by a nonthermal atmospheric plasma with relevance for medical treatment.** Sci. Rep. 8 (2018) 12195; DOI:10.1038/s41598-018-30483-w

55. Jablonowski, H.; Schmidt-Bleker, A.; Weltmann, K.-D.; von Woedtke, T.; Wende, K.: **Non-touching plasma-liquid interaction - where is aqueous nitric oxide generated? Phys.** Chem. Chem. Phys. 20 (2018) 25387-25398; DOI:10.1039/c8cp02412j

56. Jahanbakhsh, S.; Brüser, V.; Brandenburg, R.: **Single microdischarges in a barrier corona arrangement with an anodic metal pin: discharge characteristics in subsequent breakdowns.** Plasma Sources Sci. Technol. 27 (2018) 115011; DOI:10.1088/1361-6595/aaec5f

57. Kaushik, N. K.; Ghimire, B.; Li, Y.; Adhikari, M.; Veerana, M.; Kaushik, N.; Jha, N.; Adhikari, B.; Lee, S.-J.; Masur, K.; von Woedtke, T.; Weltmann, K.-D.; Choi, E. H.: **Biological and medical applications of plasma-activated media, water and solutions.** Biol. Chem. 400 (2018) 39-62; DOI:10.1515/hsz-2018-0226

58. Khakpour, A.; Methling, R.; Franke, S.; Gortschakow, S.; Uhrlandt, D.: **Vapor density and electron density determination during high-current anode phenomena in vacuum arcs.** J. Appl. Phys. 124 (2018) 243301; DOI:10.1063/1.5057753

59. Kindler, S.; Holtfreter, B.; Koppe, T.; Mksoud, M.; Lucas, C.; Seebauer, C.; Völzke, H.; Kocher, T.; Johnson, K.; Langner, S.; Albers, M.; Metelmann, H.-R.; Ittermann, T.: **Third molars and periodontal damage of second molars in the general population.** J. Clin. Periodontol. 45 (2018) 1365-1374; DOI:10.1111/jcpe.13008

60. Kondeti, S. K.; Phan, C. Q.; Wende, K.; Jablonowski, H.; Gangal, U.; Granick, J. L.; Hunter, R. C.; Bruggeman, P. J.: **Long-lived and short-lived reactive species produced by a cold atmospheric pressure plasma jet for the inactivation of Pseudomonas aeruginosa and Staphylococcus aureus.** Free Radic. Biol. Med. 124 (2018) 275-287; DOI:10.1016/j.freeradbiomed.2018.05.083

61. Krüner, B.; Odenwald, C.; Quade, A.; Kickelbick, G.; Presser, V.: **Influence of Nitrogen-Doping for Carbide-Derived Carbons on the Supercapacitor Performance in an Organic Electrolyte and an Ionic Liquid.** Batteries & Supercaps 1 (2018) 135-148; DOI:10.1002/batt.201800051

62. Krüner, B.; Schreiber, A.; Tolosa, A.; Quade, A.; Badaczewski, F.; Pfaff, T.; Smarsly, B. M.; Presser, V.: **Nitrogen-containing novolac-derived carbon beads as electrode material for supercapacitors.** Carbon 132 (2018) 220-231; DOI:10.1016/j.carbon.2018.02.029

63. Lackmann, J.-W.; Wende, K.; Verlackt, C.; Golda, J.; Volzke, J.; Kogelheide, F.; Held, J.; Bekeschus, S.; Bogaerts, A.; Schulz-von der Gathen, V.; Stapelmann, K.: **Chemical fingerprints of cold physical plasmas an experimental and computational study using cysteine as tracer compound.** Sci. Rep. 8 (2018) 7736; DOI:10.1038/s41598-018-25937-0

64. Lang, N.; Macherius, U.; Zimmermann, H.; Glitsch, S.; Wiese, M.; Röpcke, J.; van Helden, J.-P.: **RES-Q-Trace: A Mobile CEAS-Based Demonstrator for Multi-Component Trace Gas Detection in the MIR.** Sensors 18 (2018) 58; DOI:10.3390/s18072058

65. Liedtke, K. R.; Diedrich, S.; Pati, O.; Freund, E.; Flieger, R.; Heidecke, C. D.; Partecke, L. I.; Bekeschus, S.: **Cold Physical Plasma Selectively Elicits Apoptosis in Murine Pancreatic Cancer Cells In Vitro and In Ovo.** Anticancer Res. 38 (2018) 5655-5663; DOI:10.21873/anticanres.12901

66. Liedtke, K. R.; Freund, R.; Hackbarth, C.; Heidecke, C.-D.; Partecke, L.-I.; Bekeschus, S.: **A myeloid and lymphoid infiltrate in murine pancreatic tumors exposed to plasma-treated medium.** Clin. Plasma Med. 11 (2018) 10-17; DOI:10.1016/j.cpme.2018.07.001

67. Loffhagen, D.; Becker, M. M.; Czerny, A. K.; Philipp, J.; Klages, C.-P.: **Impact of hexamethyldisiloxane admixtures on the discharge characteristics of a dielectric barrier discharge in argon for thin film deposition.** Contrib. Plasma Phys. 58 (2018) 337-352; DOI:10.1002/ctpp.201700060

68. Lucke, S.; Walschus, U.; Hoene, A.; Schnabelrauch, M.; Nebe, B.; Finke, B.; Schlosser, M.: **The in vivo inflammatory and foreign body giant cell response against different poly(L-lactide-co-D/L-lactide) implants is primarily determined by material morphology rather than surface chemistry.** J. Biomed. Mater. Res. A 106 (2018) 2726-2734; DOI:10.1002/jbm.a.36500

69. Makhneva, E.; Farka, Z.; Skldal, P.; Zajckov, L.: **Cyclopropylamine plasma polymer surfaces for labelfree SPR and QCM immunosensing of Salmonella.** Sens. Actuators B Chem. 276 (2018) 447-455; DOI:10.1016/j.snb.2018.08.055

70. Malinova, I.; Mahto, H.; Brandt, F.; AL-Rawi, S.; Qasim, H.; Brust, H.; Hejazi, M.; Fettke, J.: **EARLY STARVATION1 specifically affects the phosphorylation action of starch-related dikinases.** Plant J. 95 (2018) 126-137; DOI:10.1111/tpj.13937

71. Malinova, I.; Qasim, H. M.; Brust, H.; Fettke, J.: **Parameters of Starch Granule Genesis in Chloroplasts of Arabidopsis thaliana.** Front. Plant Sci. 9 (2018) 761; DOI:10.3389/fpls.2018.00761

72. Mance, D.; Wiese, R.; Kewitz, T.; Kersten, H.: **Atmospheric pressure plasma jet for biomedical applications characterised by passive thermal probe.** Eur. Phys. J. D 72 (2018) 98; DOI:10.1140/epjd/e2018-80768-8

73. Masur, K.; Schmidt, J.; Stürmer, E.; von Woedtke, T.: **Kalte Plasmen zur Heilung chronischer Wunden.** WUND-management 12 (2018) 253-259

74. Metelmann, H.-R.; Seebauer, C.; Rutkowski, R.; Schuster, M.; Bekeschus, S.; Metelmann, P.: **Treating cancer with cold physical plasma: On the way to evidence-based medicine.** Contrib. Plasma Phys. 58 (2018) 415-419; DOI:110.1002/ctpp.201700085

75. Moerke, C.; Staehlke, S.; Rebl, H.; Finke, B.; Nebe, J. B.: **Restricted cell functions on micropillars are alleviated by surface-nanocoating with amino groups.** J. Cell Sci. 131 (2018) jcs207001; DOI:10.1242/jcs.207001

76. Müller, A.; Peglow, S.; Karnahl, M.; Kruth, A.; Junge, H.; Brüser, V.; Scheu, C.: **Morphology, Optical Properties and Photocatalytic Activity of Photo- and Plasma-Deposited Au and Au/Ag Core/Shell Nanoparticles on Titania Layers.** Nanomaterials 8 (2018) 502; DOI:10.3390/nano8070502

77. Mui, T.; Mota, R.; Quade, A.; de Oliveira Hein, L.; Kostov, K.: **Uniform surface modification of polyethylene terephthalate (PET) by atmospheric pressure plasma jet with a horn-like nozzle.** Surf. Coat. Technol. 352 (2018) 338-347; DOI:10.1016/j.surfcoat.2018.08.014

78. Murphy, A. B.; Uhrlandt, D.: **Foundations of High-Pressure Thermal Plasmas.** Plasma Sources Sci. Technol. 27 (2018) 063001; DOI:10.1088/1361-6595/aabdce

79. Nausch, M.; Achterberg, E. P.; Bach, L. T.; Brussaard, C. P.; Crawfurd, K. J.; Fabian, J.; Riebesell, U.; Stuhr, A.; Unger, J.; Wannicke, N.: **Concentrations and Uptake of Dissolved Organic Phosphorus Compounds in the Baltic Sea.** Front. Mar. Sci. 5 (2018) 386; DOI:10.3389/fmars.2018.00386

80. Nemschokmichal, S.; Tschiersch, R.; Höft, H.; Wild, R.; Bogaczyk, M.; Becker, M.; Loffhagen, D.; Stollenwerk, L.; Kettlitz, M.; Brandenburg, R.; Meichsner, J.: **Impact of volume and surface processes on the pre-ionization of dielectric barrier discharges: advanced diagnostics and fluid modelling.** Eur. Phys. J. D 72 (2018) 89; DOI:10.1140/epjd/e2017-80369-1

81. Niquet, R.; Boehm, D.; Schnabel, U.; Cullen, P.; Bourke, P.; Ehlbeck, J.: **Characterising the impact of post-treatment storage on chemistry and antimicrobial properties of plasma treated water derived from microwave and DBD sources.** Plasma Process. Polym. 15 (2018) e1700127; DOI:10.1002/ppap.201700127

82. Pasqual-Melo, G.; Gandhirajan, R.; Stoffels, I.; Bekeschus, S.: **Targeting malignant melanoma with physical plasmas.** Clin. Plasma Med. 10 (2018) 1-8; DOI:10.1016/j.cpme.2018.03.001

83. Pei, X.; Kredl, J.; Lu, X.; Kolb, J.: **Discharge modes of atmospheric pressure DC plasma jets operated with air or nitrogen.** J. Phys. D: **Appl.** Phys. 51 (2018) 384001; DOI:10.1088/1361-6463/aad4e9

84. Pipa, A. V.; Sushentsev, D.; Hamann, S.; Dufloux, C.; Ionikh, Y. Z.; Hannemann, M.; Wiese, M.; Röpcke, J.; Wollweber, J.: **Design and optical study of a microwave plasma torch in nitrogen used for the evaporation of aluminium wires.** Contrib. Plasma Phys. 58 (2018) 353-366; DOI:10.1002/ctpp.201700112

85. Puth, A.; Hamann, S.; Kusn, L.; Burlacov, I.; Dalke, A.; Spies, H.-J.; Biermann, H.; Röpcke, J.: **Spectroscopic investigations of plasma nitrocarburizing processes using an active screen made of carbon in a model reactor.** Plasma Sources Sci. Technol. 27 (2018) 75017; DOI:10.1088/1361-6595/aad035

86. Rao, J.; Lei, Y.; Jiang, S.; Li, Z.; Kolb, J. F.: **All Solid-State Rectangular Sub-Microsecond Pulse Generator for Water Treatment Application.** IEEE Trans. Plasma Sci. 46 (2018) 3359-3363; DOI:10.1109/TPS.2018.2829206

87. Reuter, S.; von Woedtke, T.; Weltmann, K.-D.: **The kINPen - a review on physics and chemistry of the atmospheric pressure plasma jet and its applications.** J. Phys. D: **Appl.** Phys. 51 (2018) 233001; DOI:10.1088/1361-6463/aab3ad

88. Röpcke, J.; Loffhagen, D.; von Wahl, E.; Nave, A.; Hamann, S.; van Helden, J.-P.; Lang, N.; Kersten, H.: **On improved understanding of plasma-chemical processes in complex low-temperature plasmas.** Eur. Phys. J. D 72 (2018) 87; DOI:10.1140/epjd/e2017-80363-7

89. Sagwal, S. K.; Pasqual-Melo, G.; Bodnar, Y.; Gandhirajan, R. K.; Bekeschus, S.: **Combination of chemotherapy and physical plasma elicits melanoma cell death via upregulation of SLC22A16.** Cell Death Dis. 9 (2018) 1179; DOI:10.1038/s41419-018-1221-6

90. Sava, I.; Kruth, A.; Kolb, J. F.; Miron, C.: **Optical properties of polyimides films treated by nanosecond pulsed electrical discharges in water.** Jpn. J. Appl. Phys. 57 (2018) 0102BF; DOI:10.7567/JJAP.57.0102BF

91. Schäfer, J.; Sigeneger, F.; Foest, R.; Loffhagen, D.; Weltmann, K.-D.: **On a non-thermal atmospheric pressure plasma jet used for the deposition of silicon-organic films.** Eur. Phys. J. D 72 (2018) 90; DOI:10.1140/epjd/e2017-80364-6

92. Schäfer, J.; Sigeneger, F.; Šperka, J.; Rodenburg, C.; Foest, R.: **Searching for order in atmospheric pressure plasma jets.** Plasma Phys. Control. Fusion 60 (2018) 14038; DOI:10.1088/1361-6587/aa8f14

93. Schmidt, A.; Bekeschus, S.: **Redox for Repair: Cold Physical Plasmas and Nrf2 Signaling Promoting Wound Healing.** Antioxidants 7 (2018) 146; DOI:10.3390/antiox7100146

94. Schmidt, M.; Timmermann, E.; Kettlitz, M.; Brandenburg, R.: **Combined Electric Wind and Non-Thermal Plasma for Gas Cleaning.** Int. J. Plasma Environ. Sci. Technol. 11 (2018) 133-137

95. Schnabel, U.; Schmidt, C.; Stachowiak, J.; Bösel, A.; Andrasch, M.; Ehlbeck, J.: **Plasma processed air for biological decontamination of PET and fresh plant tissue.** Plasma Process. Polym. 15 (2018) 1600057; DOI:10.1002/ppap.201600057

96. Schuster, M.; Rutkowski, R.; Hauschild, A.; Shojaei, R. K.; von Woedtke, T.; Rana, A.; Bauer, G.; Metelmann, P.; Seebauer, C.: **Side effects in cold plasma treatment of advanced oral cancerClinical data and biological interpretation.** Clin. Plasma Med. 10 (2018) 9-15; DOI:10.1016/j.cpme.2018.04.001

97. Seebauer, C.; Lucas, C.; Kindler, S.; Metelmann, H.-R.: **Wundmanagement Biologie und Störung der Wundheilung.** MKG-Chirurg 11 (2018) 277-287; DOI:10.1007/s12285-018-0172-3

98. Sievers, G.; Vidakovic-Koch, T.; Walter, C.; Steffen, F.; Jakubith, S.; Kruth, A.; Hermsdorf, D.; Sundmacher, K.; Brüser, V.: **Ultra-low loading Pt-sputtered gas diffusion electrodes for oxygen reduction reaction.** J. Appl. Electrochem. 48 (2018) 221-232; DOI:10.1007/s10800-018-1149-7

99. Staehlke, S.; Rebl, H.; Finke, B.; Mueller, P.; Gruening, M.; Nebe, B.: **Enhanced calcium ion mobilization in osteoblasts on amino group containing plasma polymer nanolayer.** Cell Biosci. 8 (2018) 22; DOI:10.1186/s13578-018-0220-8

100. Stamenković, S. N.; Marković, V. L.; Jovanović, A. P; Stankov, M. N.: **Generalization of electron avalanche statistics based on negative binomial distribution - multielectron initiation and Gaussian approximation.** J. Instrum. 13 (2018) P12002; DOI:10.1088/1748-0221/13/12/P12002

101. Stancu, E. C.; Ionita, M. D.; Ionita, E. R; Teodorescu, M.; Radu, M. T.; Dinescu, G.: **Processing of polyvinyl chloride surfaces with atmospheric pressure dielectric barrier discharges for urology applications.** Romanian J. Phys. 63 (2018) 705; http://www.nipne.ro/rjp/2018_63_9-10/RomJPhys.63.705.pdf

102. Steuer, A.; Wolff, C. M.; von Woedtke, T.; Weltmann, K.-D.; Kolb, J. F.: **Cell stimulation versus cell death induced by sequential treatments with pulsed electric fields and cold atmospheric pressure plasma.** PLoS One 13 (2018) e0204916; DOI:10.1371/journal.pone.0204916

103. Stranak, V.; Bogdanowicz, R.; Sezemsky, P.; Wulff, H.; Kruth, A.; Smietana, M.; Kratochvil, J.; Cada, M.; Hubicka, Z.: **Towards high quality ITO coatings: The impact of nitrogen admixture in HiPIMS discharges.** Surf. Coat. Technol. 335 (2018) 126-133; DOI:10.1016/j.surfcoat.2017.12.030

104. Sudhakaran, M.S.P; Sultana, L.; Hossain, M.; Pawlat, J.; Diatczyk, J.; Brüser, V.; Reuter, S.; Mok, Y. S.: **Ironceria spinel (FeCe2O4) catalyst for dry reforming of propane to inhibit carbon formation.** J. Ind. Eng. Chem. 61 (2018) 142-151; DOI:10.1016/j.jiec.2017.12.011

105. Sun, A.; Becker, M. M.; Loffhagen, D.: **PIC/MCC simulation of capacitively coupled discharges in helium: boundary effects.** Plasma Sources Sci. Technol. 27 (2018) 054002; DOI:10.1088/1361-6595/aac30a

106. Timmermann, E.; Prehn, F.; Schmidt, M.; Höft, H.; Brandenburg, R.; Kettlitz, M.: **Indoor air purification by dielectric barrier discharge combined with ionic wind: physical and microbiological investigations.** J. Phys. D: **Appl.** Phys. 51 (2018) 164003; DOI:10.1088/1361-6463/aab48b

107. Tolosa, A.; Fleischmann, S.; Grobelsek, I.; Quade, A.; Lim, E.; Presser, V.: **Binder-Free Hybrid TitaniumNiobium Oxide/Carbon Nanofiber Mats for Lithium-Ion Battery Electrodes.** ChemSusChem 11 (2018) 159-170; DOI:10.1002/cssc.201701927

108. Vandenbossche, M.; Dorst, J.; Amberg, M.; Schütz, U.; Rupper, P.; Heuberger, M.; Hegemann, D.: **Functionality and chemical stability of plasma polymer films exhibiting a vertical cross-linking gradient in their subsurface.** Polym. Degrad. Stab. 156 (2018) 259-268; DOI:10.1016/j.polymdegradstab.2018.09.015

109. von Woedtke, T.; Weltmann, K.-D.; Metelmann, H.-R.; Bekeschus, S.; Emmert, S.; Lademann, J.; Viöl, W.: **Letters.** J. Wound Care 27 (2018) 892-893; DOI:10.12968/jowc.2018.27.12.892

110. Wannicke, N.; Benavides, M.; Dalsgaard, T.; Dippner, J. W.; Montoya, J. P.; Voss, M.: **New Perspectives on Nitrogen Fixation Measurements Using 15N2 Gas.** Front. Mar. Sci. 5 (2018) 120; DOI:10.3389/fmars.2018.00120

111. Wannicke, N.; Frey, C.; Law, C. S.; Voss, M.: **The response of the marine nitrogen cycle to ocean acidification.** Glob. Change Biol. 24 (2018) 5031-5043; DOI:10.1111/gcb.14424

112. Winter, J.; Nishime, T. M. C.; Bansemer, R.; Balazinski, M.; Wende, K.; Weltmann, K.-D.: **Enhanced atmospheric pressure plasma jet setup for endoscopic applications.** J. Phys. D: **Appl.** Phys. 52 (2018) 24005; DOI:10.1088/1361-6463/aae817

113. Winter, J.; Nishime, Th.; Glitsch, S.; Lühder, H.; Weltmann, K.-D.: **On the development of a deployable cold plasma endoscope.** Contrib. Plasma Phys. 58 (2018) 404-414; DOI:10.1002/ctpp.201700127

114. Xaubet, M.; Baudler, J.-S.; Gerling, T.; Giuliani, L.; Minotti, F.; Grondona, D.; vonWoedtke, T.; Weltmann, K.-D.: **Design optimization of an air atmospheric pressure plasma-jet device intended for medical use.** Plasma Process. Polym. 15 (2018) 1700211; DOI:10.1002/ppap.201700211

115. Yusupov, M.; Lackmann, J.-W.; Razzokov, J.; Kumar, S.; Stapelmann, K.; Bogaerts, A.: **Impact of plasma oxidation on structural features of human epidermal growth factor.** Plasma Process. Polym. 15 (2018) 1800022; DOI:10.1002/ppap.201800022

116. Zhang, T.; Liao, Z.; Sandonas, L. M.; Dianat, A.; Liu, X.; Xiao, P.; Amin, I.; Gutierrez, R.; Chen, T.; Zschech, E.; Cuniberti, G.; Jordan, R.: **Polymerization driven monomer passage through monolayer chemical vapour deposition graphene.** Nat. Commun. 9 (2018) 4051; DOI:10.1038/s41467-018-06599-y

117. Zhang, T.; Rodriguez, R. D.; Amin, I.; Gasiorowski, J.; Rahaman, M.; Sheng, W.; Kalbacova, J.; Sheremet, E.; Zahn, D.; Jordan, R.: **Bottom-up fabrication of graphene-based conductive polymer carpets for optoelectronics.** J. Mater. Chem. C 6 (2018) 4919-4927; DOI:10.1039/C8TC00554K

118. Zimmermann, S.; Haase, M.; Lang, N.; Röpcke, J.; Schulz, S. E.; Otto, T.: **The role of plasma analytics in leading-edge semiconductor technologies.** Contrib. Plasma Phys. 58 (2018) 367-376; DOI:10.1002/ctpp.201700086

ARTICLES IN PEER-REVIEWED JOURNALS 2019

1. Abrams, K. J.; Dapor, M.; Stehling, N.; Azzolini, M.; Kyle, S. J.; Schäfer, J.; Quade, A.; Mika, F.; Kratky, S.; Pokorna, Z.; Konvalina, I.; Mehta, D.; Black, K.; Rodenburg, C.: **Making Sense of Complex Carbon and Metal/Carbon Systems by Secondary Electron Hyperspectral Imaging.** Adv. Sci. 6 (2019) 1900719; DOI:10.1002/advs.201900719

2. Almuina-Villar, H.; Lang, N.; Anca-Couce, A.; Röpcke, J.; Behrendt, F.; Dieguez-Alonso, A.: **Application of laser-based diagnostics for characterization of the influence of inorganics on the slow pyrolysis of woody biomass.** J. Anal. Appl. Pyrolysis 140 (2019) 125-136; DOI:10.1016/j.jaap.2019.03.004

3. Baeva, M.; Loffhagen, D.; Becker, M. M.; Uhrlandt, D.: **Fluid Modelling of DC Argon Microplasmas: Effects of the Electron Transport Description.** Plasma Chem. Plasma Process. 39 (2019) 949-968; DOI:10.1007/s11090-019-09994-5

4. Baeva, M.; Loffhagen, D.; Uhrlandt, D.: **Unified Non-equilibrium Modelling of Tungsten-Inert Gas Microarcs in Atmospheric Pressure Argon.** Plasma Chem. Plasma Process. 39 (2019) 1359; DOI:10.1007/s11090-019-10020-x

5. Baeva, M.; Siewert, E.; Uhrlandt, D.: **Comparative Studies of Low-intensity Short-length Arcs.** Plasma Phys. Technol. 6 (2019) 56-59; DOI:10.14311/ppt.2019.1.56

6. Baeva, M.; Uhrlandt, D.: **Nonequilibrium simulation analysis of the power dissipation and the pressure produced by TIG welding arcs.** Weld. World 63 (2019) 377-387; DOI:10.1007/s40194-018-0663-x

7. Bansemer, R.; Schmidt-Bleker, A.; van Rienen, U.; Weltmann, K.-D.: **Monitoring of a dielectric barrier discharge-based process using the gas gap voltage.** Plasma Sources Sci. Technol. 28 (2019) 25002; DOI:10.1088/1361-6595/ab0034

8. Becerra, M.; Pettersson, J.; Franke, S.; Gortschakow, S.: **Temperature and pressure profiles of an ablation-controlled arc plasma in air.** J. Phys. D: Appl. Phys. 52 (2019) 434003; DOI:10.1088/1361-6463/ab34b6

9. Becker, M.; Quabius, S.; Kewitz, T.; Hansen, L.; Becker, G.; Kern, M.; Kersten, H.; Harder, S.: **In vitro proinflammatory gene expression changes in human whole blood after contact with plasma-treated implant surfaces.** J. Craniomaxillofac. Surg. 47 (2019) 1255-1261; DOI:10.1016/j.jcms.2019.05.004

10. Bekeschus, S.; Favia, P.; Robert, E.; von Woedtke, T.: **White paper on plasma for medicine and hygiene: Future in plasma health sciences.** Plasma Process. Polym. 16 (2019) 1800033; DOI:10.1002/ppap.201800033

11. Bekeschus, S.; Freund, E.; Spadola, C.; Privat-Maldonado, A.; Hackbarth, C.; Bogaerts, A.; Schmidt, A.; Wende, K.; Weltmann, K.-D.; von Woedtke, T.; Heidecke, C.-D.; Partecke, L.-I.; Käding, A.: **Risk Assessment of kINPen Plasma Treatment of Four Human Pancreatic Cancer Cell Lines with Respect to Metastasis.** Cancers 11 (2019) 1237; DOI:10.3390/cancers11091237

12. Bekeschus, S.; Lippert, M.; Diepold, K.; Chiosis, G.; Seufferlein, T.; Azoitei, N.: **Physical plasma-triggered ROS induces tumor cell death upon cleavage of HSP90 chaperone.** Sci. Rep. 9 (2019) 4112; DOI:10.1038/s41598-019-38580-0

13. Bekeschus, S.; Schütz, C. S.; Nießner, F.; Wende, K.; Weltmann, K.-D.; Gelbrich, N.; v. Woedtke, T.; Schmidt, A.; Stope, M. B.: **Elevated H2AX Phosphorylation Observed with kINPen Plasma Treatment Is Not Caused by ROS-Mediated DNA Damage but Is the Consequence of Apoptosis.** Oxid. Med. Cell. Longev. 2019 (2019) 8535163; DOI:10.1155/2019/8535163

14. Bekeschus, S.; Seebauer, C.; Wende, K.; Schmidt, A.: **Physical plasma and leukocytes immune or reactive?.** Biol. Chem. 400 (2019) 63-75; DOI:10.1515/hsz-2018-0224

15. Bernhardt, T.; Semmler, M. L.; Schäfer, M.; Bekeschus, S.; Emmert, S.; Emmert, S.; Boeckmann, L.: **Plasma Medicine: Applications of Cold Atmospheric Pressure Plasma in Dermatology.** Oxid. Med. Cell. Longev. 2019 (2019) 3873928; DOI:10.1155/2019/3873928

16. Bonitz, M.; Filinov, A.; Abraham, J.-W.; Balzer, K.; Kählert, H.; Pehlke, E.; Bronold, F. X.; Pamperin, M.; Becker, M.; Loffhagen, D.; Fehske, H.: **Towards an integrated modeling of the plasma-solid interface.** Front. Chem. Sci. Eng. 13 (2019) 201-237; DOI:10.1007/s11705-019-1793-4

17. Borges, A. C.; Nishime, T. M. C.; de Moura Rovetta, S.; Lima, G.M.G.; Kostov, K. G.; Thim, G. P.; de Menezes, B. R. C., Machado, J. P. B.; Koga-Ito, C. Y.: **Cold Atmospheric Pressure Plasma Jet Reduces Trichophyton rubrum Adherence and Infection Capacity.** Mycopathologia 184 (2019) 585-595; DOI:10.1007/s11046-019-00375-2

18. Brandenburg, R.; Bogaerts, A.; Bongers, W.; Fridman, A.; Fridman, G.; Locke, B. R.; Miller, V.; Reuter, S.; Schiorlin, M.; Verreycken, T.; Ostrikov, K.: **White paper on the future of plasma science in environment, for gas conversion and agriculture, # Plasma Process.** Polym. 16 (2019) 1700238; DOI:10.1002/ppap.201700238

19. Brandenburg, R.; Jahanbakhsh, S.; Schiorlin, M.; Schmidt, M.: **About the Development and Dynamics of Microdischarges in Toluene-Containing Air.** Plasma Chem. Plasma Process. 39 (2019) 667-682; DOI:10.1007/s11090-019-09971-y

20. Bruno, G.; Heusler, T.; Lackmann, J.-W.; v. Woedtke, T.; Weltmann, K.-D.; Wende, K.: **Cold physical plasma-induced oxidation of cysteine yields reactive sulfur species (RSS).** Clin. Plasma Med. 14 (2019) 100083; DOI:10.1016/j.cpme.2019.100083

21. Carrara, I. M.; Melo, G. P.; Bernardes, S. S.; Neto, F. S.; Ramalho, L. N. Z.; Marinello, P. C.; Luiz, R. C.; Cecchini, R.; Cecchini, A. L.: **Looking beyond the skin: Cutaneous and systemic oxidative stress in UVB-induced squamous cell carcinoma in hairless mice.** J. Photochem. Photobiol. B 195 (2019) 17-26; DOI:10.1016/j.jphotobiol.2019.04.007

22. Cirocka, A.; Zarzeczanska, D.; Wcislo, A.; Ryl, J.; Bogdanowicz, R.; Finke, B.; Ossowski, T.: **Tuning of the electrochemical properties of transparent fluorine-doped tin oxide electrodes by microwave pulsed-plasma polymerized allylamine.** Electrochim. Acta 313 (2019) 432-440; DOI:10.1016/j.electacta.2019.05.046

23. Cvelbar, U.; Walsh, J.; Cernk, M.; de Vries, H.; Reuter, S.; Belmonte, T.; Corbella, C.; Miron, C.; Hojnik, N.; Jurov, A.; Puliyalil, H.; Gorjanc, M.; Schäfer, J.; Polak, M.; Weltmann, K.-D. et al.: **White paper on the future of plasma science and technology in plastics and textiles.** Plasma Process. Polym. 16 (2019) 1700228; DOI:10.1002/ppap.201700228

24. Dalke, A.; Burlacov, I.; Hamann, S.; Puth, A.; Böcker, J.; Spies, H.-J.; Röpcke, J.; Biermann, H.: **Solid carbon active screen plasma nitrocarburizing of AISI 316L stainless steel: Influence of N2-H2 gas composition on structure and properties of expanded austenite.** Surf. Coat. Technol. 357 (2019) 1060-1068; DOI:10.1016/j.surfcoat.2018.10.095

25. Derevyankin, P.; Frolov, V.; Gonzalez, D.; Gortschakow, S.; Methling, R.; Uhrlandt, D.: **Analysis of erosion resistance of CuC arcing contacts manufactured by plasma spraying technology.** Plasma Phys. Technol. 6 (2019) 123-126; DOI:10.14311/ppt.2019.2.123

26. Esaifan, M.; Warr, L. N.; Grathoff, G.; Meyer, T.; Schafmeister, M.-T.; Kruth, A.; Testrich, H.: **Synthesis of Hydroxy-Sodalite/Cancrinite Zeolites from Calcite-Bearing Kaolin for the Removal of Heavy Metal, Ions in Aqueous Media, # Minerals 9 (2019) 484; DOI:10.**3390/min9080484

27. Freund, E.; Liedtke, K. R.; Gebbe, R.; Heidecke, A. K.; Partecke, L.-I.; Bekeschus, S.: **In Vitro Anticancer Efficacy of Six Different Clinically Approved Types of Liquids Exposed to Physical Plasma.** IEEE Trans. Radiat. Plasma Med. Sci. 3 (2019) 588-596; DOI:10.1109/TRPMS.2019.2902015

28. Freund, E.; Liedtke, K. R.; van der Linde, J.; Metelmann, H.-R.; Heidecke, C.-D.; Partecke, L.-I.; Bekeschus, S.: **Physical plasma-treated saline promotes an immunogenic phenotype in CT26 colon cancer cells in vitro and in vivo.** Sci. Rep. 9 (2019) 634; DOI:10.1038/s41598-018-37169-3

29. Freund, E.; Moritz, J.; Stope, M.; Seebauer, C.; Schmidt, A.; Bekeschus, S.: **Plasma-Derived Reactive Species Shape a Differentiation Profile in Human Monocytes.** Appl. Sci. 9 (2019) 2530; DOI:10.3390/app9122530

30. Ghimire, B.; Szili, E. J.; Lamichhane, P.; Short, R. D.; Lim, J. S.; Attri, P.; Masur, K.; Weltmann, K.-D.; Hong, S. H.; Choi, E. H.: **The role of UV photolysis and molecular transport in the generation of reactive species in a tissue model with a cold atmospheric pressure plasma jet.** Appl. Phys. Lett. 114 (2019) 93701; DOI:10.1063/1.5086522

31. Gonzalez, D.; Gortschakow, S.; Yu, S.; Werner, F.: **Investigation of the arc characteristics of switching dc arcs on hydrogen containing gas mixtures.** Plasma Phys. Technol. 6 (2019) 69-72; DOI:10.14311/ppt.2019.1.69

32. Gortschakow, S.; Gonzalez, D.; Yub, S.; Werner, F.: **3d analysis of low-voltage gas-filled dc switch using simplified arc model.** Plasma Phys. Technol. 6 (2019) 65-68; DOI:10.14311/ppt.2019.1.65

33. Gortschakow, S.; Kalanov, D.; Golubovski, Y.: **Influence of resonance radiation transport on chemical equilibrium in an argon arc.** ACS Appl. Mater. Interfaces 6 (2019) 119-122; DOI:10.14311/ppt.2019.2.119

34. Hahn, V.; Dikyol, C.; Altrock, B.; Schmidt, M.; Wende, K.; Ercan, U.K.; Weltmann, K.-D.; von Woedtke, T.: Plasma-mediated inactivation of Escherichia coli: **Influence of protein on wet surface and in liquid medium.** Plasma Process. Polym. 16 (2019) 1800164; DOI:10.1002/ppap.201800164

35. Handorf, O.; Schnabel, U.; Bösel, A.; Weihe, T.; Bekeschus, S.; Graf, A.C.; Riedel, K.; Ehlbeck, J.: **Antimicrobial effects of microwave-induced plasma torch (MiniMIP) treatment on Candida albicans biofilms.** Microb Biotechnol. 12 (2019) 1034-1048; DOI:10.1111/1751-7915.13459

36. Harhausen, J.; Foest, R.; Stenzel, O.; Wilbrandt, S.; Franke, C.; Brinkmann, R. P.: **Concepts for in situ characterization and control of plasma ion assisted deposition processes.** Thin Solid Films 673 (2019) 94-103; DOI:10.1016/j.tsf.2019.01.038

37. Hasse, S.; Müller, M.-C.; Schallreuter, K. U.; von Woedtke, T.: **Stimulation of melanin synthesis in melanoma cells by cold plasma.** Biol. Chem. 400 (2019) 101-109; DOI:10.1515/hsz-2018-0223

38. Hasse, S.; Seebauer, C.; Wende, K.; Schmidt, A.; Metelmann, H.-R.; von Woedtke, T.; Bekeschus, S.: **Cold Argon Plasma as Adjuvant Tumour Therapy on Progressive Head and Neck Cancer: A Preclinical Study.** Appl. Sci. 9 (2019) 2061; DOI:10.3390/app9102061

39. Heusler, T.; Bruno, G.; Bekeschus, S.; Lackmann, J.-W.; v. Woedtke, T.; Wende, K.: **Can the effect of cold physical plasma-derived oxidants be transported via thiol group oxidation?.** Clin. Plasma Med. 14 (2019) 100086; DOI:10.1016/j.cpme.2019.100086

40. imek, M.; Cernk, M.; Kylin, O.; Foest, R.; Hegemann, D.; Martini, R.: **White paper on the future of plasma science for optics and glass.** Plasma Process. Polym. 16 (2019) 1700250; DOI:10.1002/ppap.201700250

41. Jablonowski, L.; Kocher, T.; Schindler, A.; Müller, K.; Dombrowski, F.; von Woedtke, T.; Arnold, T.; Lehmann, A.; Rupf, S.; Evert, M.; Evert, K.: **Side effects by oral application of atmospheric pressure plasma on the mucosa in mice.** PLoS One 14 (2019) e0215099; DOI:10.1371/journal.pone.0215099

42. Jahanbakhsh, S.; Hoder, T.; Brandenburg, R.: **Correlation between electric field, current and photon emission in subsequent barrier corona microdischarges, # ACS Appl.** Mater. Interfaces 126 (2019) 193305; DOI:10.1063/1.5124363

43. Jovanovic, A. P.; Stamenkovic, S N.; Stankov, M. N.; Markovic, V. L.: **Monte Carlo simulation of electron avalanches and avalanche size distributions in methane.** Contrib. Plasma Phys. 59 (2019) 272-283; DOI:10.1002/ctpp.201800034

44. Kalanov, D.; Kozakov, R.; Siasko, A.; Bösel, A.; Golubovskii, Y.; Gortschakow, S.: **Spatially resolved LAAS/OES diagnostics of a free-burning Ar arc: measurements of excited atom densities.** J. Phys. D: **Appl.** Phys. 52 (2019) 75204; DOI:10.1088/1361-6463/aaf5c1

45. Khabipov, A.; Käding, A.; Liedtke, K. R., Freund, E.; Partecke, L. I.; Bekeschus, S.: **RAW 264.**7 Macrophage Polarization by Pancreatic Cancer Cells - A Model for Studying Tumour-promoting Macrophages. Anticancer Res. 39 (2019) 2871-2882; DOI:10.21873/anticanres.13416

46. Khakpour, A.; Franke, S.; Gortschakow, S.; Methling, R.; Popov, S.; Schneider, A. V.; Uhrlandt, D.: **Investigation of Anode Plume in Vacuum Arcs using different Optical Diagnostic Methods.** IEEE Trans. Plasma Sci. 47 (2019) 3488-3495; DOI:10.1109/TPS.2019.2904458

47. Khakpour, A.; Franke, St.; Methling, R.; Gortschakow, S.; Uhrlandt, D.; Imani, M. T.: **An Improved Arc Model for Vacuum Arc Regarding Anode Spot Modes.** IEEE Trans. Dielectr. and Electr. Insul. 26 (2019) 120-128; DOI:10.1109/TDEI.2018.007587

48. Khakpour, A.; Gortschakow, S.; Franke, St.; Methling, R.; Popov, S.; Uhrlandt, D.: **Determination of Cr density during high-current anode modes in vacuum arc.** J. Appl. Phys. 125 (2019) 133301; DOI:10.1063/1.5086543

49. Khalili, M.; Daniels, L.; Lin, A.; Krebs, F. C.; Snook, A. E.; Bekeschus, S.; Bowne, W. B.; Miller, V.: **Non-thermal plasma-induced immunogenic cell death in cancer.** J. Phys. D: **Appl.** Phys. 52 (2019) 423001; DOI:10.1088/1361-6463/ab31c1

50. Ki, S. H.; Masur, K.; Baik, K. Y.; Ha Choi, E.: **Effects of humidity on room disinfection by dielectric barrier discharge plasma.** J. Phys. D: **Appl.** Phys. 52 (2019) 425204; DOI:10.1088/1361-6463/ab3066

51. Krewing, M.; Jarzina, F.; Dirks, T.; Schubert, B.; Benedikt, J.; Lackmann, J.-W.; Bandow, J. E.: **Plasma-sensitive Escherichia coli mutants reveal plasma resistance mechanisms.** J. R. Soc. Interface 16 (2019) 20180846; DOI:10.1098/rsif.2018.0846

52. Krewing, M.; Stepanek, J. J.; Cremers, C.; Lackmann, J.-W.; Schubert, B.; Müller, A.; Awakowicz, P.; Leichert, L. I. O.; Jakob, U.; Bandow, J. E.: **The molecular chaperone Hsp33 is activated by atmospheric-pressure plasma protecting proteins from aggregation.** J. R. Soc. Interface 16 (2019) 20180966; DOI:10.1098/rsif.2018.0966

53. Kübel, J. M.; Botha, C.; Bucka, A.; Höpfner, J.; Zimmermann, H.; Godejohann, M.; Wilhelm, M.: **A New Quantum Cascade IR-Laser Online Detector: Chemical-Sensitive Size-Exclusion Chromatography Measurement at Unprecedented Low Levels.** Macromol. Rapid Commun. 40 (2019) 1900228; DOI:10.1002/marc.201900228

54. Lackmann, J.-W.; Bruno, G.; Jablonowski, H.; Kogelheide, F.; Offerhaus, B.; Held, J.; Schulz-von der Gathen, S.; Stapelmann, K.; v. Woedtke, T.; Wende, K.: **Nitrosylation vs. oxidation - How to modulate cold physical plasmas for biological applications**. PLoS One 14 (2019) e0216606; DOI:10.1371/journal.pone.0216606

55. Li, H.; Methling, R.; Franke, S.; Uhrlandt, D.; Gortschakow, S.; Marseille, T.; Kurrat, M.; Geng, Y.: **Spectroscopic Analysis of Anode Surface Thermal Emission With Single and Dual Vacuum Arc Columns.** IEEE Trans. Plasma Sci. 47 (2019) 5204-5213; DOI:10.1109/TPS.2019.2940760

56. Lukowski, G.; Weihe, T.; Köhnlein, J.; Schlüter, R.; Schultze, N.; Quade, A.; Wendler, C.; Rackow, K.; Dittrich, A.; Werner, S.; Ehlbeck, J.; Weltmann, K.-D.: **Renewable nano-structured coatings on medical devices prevent the transmission of clinically relevant pathogens.** Surf. Coat. Technol. 366 (2019) 227-237; DOI:10.1016/j.surfcoat.2019.02.066

57. Markovic, V.Lj.; Stamenkovic, S.N., Jovanovic, A.P.: **Electron avalanche statistics for multielectron initiation with homogeneous and inhomogeneous Poisson emission.** JInst 14 (2019) P06009; DOI:10.1088/1748-0221/14/06/P06009

58. Matthes, R; Jablonowski, L; Holtfreter, B; Gerling, T; von Woedtke, T; Kocher, T: **Fibroblast growth on zircon ceramic and titanium disks after application with cold atmospheric pressure plasma devices or with antiseptics.** Int. J. Oral. Maxillofac. Implants 34 (2019) 809-818; DOI:10.11607/jomi.7285

59. Mayerhöfer, T.; Pipa, A. V.; Popp, J.: **Beers Law - Why Integrated Absorbance Depends Linearly on Concentration.** ChemPhysChem 20 (2019) 2748-2753; DOI:10.1002/cphc.201900787

60. Methling, R.; Franke, S.; Götte, N.; Wetzeler, S.; Uhrlandt, D.: **Analysis of C2 swan bands in ablation-dominated arcs in CO2 atmosphere.** Plasma Phys. Technol. 6 (2019) 82-86; DOI:10.14311/ppt.2019.1.82

61. Methling, R.; Hempel, F.; Baeva, M.; Trautvetter, T.; Baierl, H.; Foest, R.: **On the Interaction of a Microwave Excited Oxygen Plasma with a Jet of Precursor Material for Deposition Applications.** Plasma Phys. Technol. 6 (2019) 243-246; DOI:10.14311/ppt.2019.3.243

62. Meyer, T.; Bae, H.; Hasse, S.; Winter, J.; von Woedtke, T.; Schmitt, M.; Weltmann, K.-D.; Popp, J.: **Multimodal Nonlinear Microscopy for Therapy Monitoring of Cold Atmospheric Plasma Treatment.** Micromachines 10 (2019) 564; DOI:10.3390/mi10090564

63. Mohsni, C.; Baeva, M.; Franke, S.; Gortschakow, S.; Gonzalez, D.; Araoud, Z.; Charrada, K.: **Modelling and experimental investigations of dc electric arcs in argon and carbon dioxide.** Plasma Phys. Technol. 6 (2019) 51-55; DOI:10.14311/ppt.2019.1.51

64. Nave, A. S.; Pipa, A. V.; Davies, P. B.; Röpcke, J.; v. Helden, J.-P. H.: **Determining a Line Strength in the nu-3 Band of the Silyl Radical Using Quantum Cascade Laser Absorption Spectroscopy.** J. Phys. Chem. A 123 (2019) 10030-10039; DOI:10.1021/acs.jpca.9b06351

65. Nebe, J. B.; Rebl, H.; Schlosser, M.; Staehlke, S.; Gruening, M.; Weltmann, K.-D.; Walschus, U.; Finke, B.: **Plasma Polymerized Allylamine - The Unique Cell-Attractive Nanolayer for Dental Implant Materials.** Polymers 11 (2019) 1004; DOI:10.3390/polym11061004

66. Pettersson, J.; Becerra, M.; Franke, St.; Gortschakow, S.: **Spectroscopic and Photographic Evaluation of the Near-Surface Layer Produced by Arc-Induced Polymer Ablation.** IEEE Trans. Plasma Sci. 47 (2019) 1851-1858; DOI:10.1109/TPS.2019.2898632

67. Pipa, A. V.; Brandenburg, R.: **The Equivalent Circuit Approach for the Electrical Diagnostics of Dielectric Barrier Discharges: The Classical Theory and Recent Developments.** Atoms 7 (2019) 14; DOI:10.3390/atoms7010014

68. Privat-Maldonado, A.; Schmidt, A.; Lin, A.; Weltmann, K.-D.; Wende, K.; Bogaerts, A.; Bekeschus, S.: **ROS from Physical Plasmas: Redox Chemistry for Biomedical Therapy.** Oxid. Med. Cell. Longev. 2019 (2019) 9062098; DOI:10.1155/2019/9062098

69. Rataj, R.; Höft, H.; Kolb, J. F.: **Reillumination of submicrosecond pulsed corona-like discharges in water.** Plasma Sources Sci. Technol. 28 (2019) 125002; DOI:10.1088/1361-6595/ab54e0

70. Rödder, K.; Moritz, J.; Miller, V.; Weltmann, K.-D.; Metelmann, H.-R.; Gandhirajan, R.; Bekeschus, S.: **Activation of Murine Immune Cells upon Co-culture with Plasma-treated B16F10 Melanoma Cells.** Appl. Sci. 9 (2019) 660; DOI:10.3390/app9040660

71. Salazar, A.; Hunemorder, P.; Rabeah, J.; Quade, A.; Jagadeesh, R. V.; Mejia, E.: **Synergetic Bimetallic Oxidative Esterification of 5-Hydroxymethylfurfural under Mild Conditions.** ACS Sustain. Chem. Eng. 7 (2019) 12061-12068; DOI:10.1021/acssuschemeng.9b00914

72. Sava, I.; Asandulesa, M.; Zocher, K.; Kruth, A.; Kolb, J. F.; Bodnar, W.; Witte, K.; Ishizakid, T.; Miron, C.: **Electrical and mechanical properties of polyimide films treated by plasma formed in water and isopropanol.** React. Funct. Polym. 134 (2019) 22-30; DOI:10.1016/j.reactfunctpolym.2018.11.005

73. Scharf, C.; Eymann, C.; Emicke, P.; Bernhardt, J.; Wilhelm, M.; Görries, F.; Winter, J.; von Woedtke, T.n; Darm, K.; Daeschlein, G.; Steil, L.; Hosemann, W.; Beule, A.: **Improved Wound Healing of Airway Epithelial Cells Is Mediated by Cold Atmospheric Plasma: A Time Course-Related Proteome Analysis.** Oxid. Med. Cell. Longev. 2019 (2019) 7071536; DOI:10.1155/2019/7071536

74. Schmalhofer, M.-L.; Markus, M. R. P.; Gras, J. C.; Kopp, J.; Janowitz, D.; Grabe, H.-J.; Groß, S.; Ewert, R.; Gläser, S.; Albrecht, D.; Eiffler, I.; Völzke, H.; Friedrich, N.; Nauck, M.; Steveling, A.; Könemann, S.; Wenzel, K.; Felix, S. B.; et al.: **Sex-Specific Associations of Brain-Derived Neurotrophic Factor and Cardiorespiratory Fitness in the General Population.** Biomolecules 9 (2019) 630; DOI:10.3390/biom9100630

75. Schmidt, A.; Bekeschus, S.; Jarick, K.; Hasse, S.; von Woedtke, T.; Wende, K.: **Cold Physical Plasma Modulates p53 and Mitogen-Activated Protein Kinase Signaling in Keratinocytes.** Oxid. Med. Cell. Longev. 2019 (2019) 7017363; DOI:10.1155/2019/7017363

76. Schmidt, A.; von Woedtke, T.: **Highlight Issue: Plasma Medicine.** Biol. Chem. 400 (2019) 1-2; DOI:10.1515/hsz-2018-0410

77. Schmidt, A.; von Woedtke, T.; Vollmar, B.; Hasse, S.; Bekeschus, S.: **Nrf2 signaling and inflammation are key events in physical plasma-spurred wound healing.** Theranostics 9 (2019) 1066-1084; DOI:10.7150/thno.29754

78. Schmidt, M.; Hahn, V.; Altrock, B.; Gerling, T.; Gerber, I. C.; Weltmann, K.-D.; von Woedtke, T.: **Plasma-Activation of Larger Liquid Volumes by an Inductively-Limited Discharge for Antimicrobial Purposes.** Appl. Sci. 9 (2019) 2150; DOI:10.3390/app9102150

79. Schnabel, U.; Andrasch, M.; Stachowiak, J.; Weit, C.; Weihe, T.; Schmidt, C.; Muranyi, P.; Schlüter, O.; Ehlbeck, J.: **Sanitation of fresh-cut endive lettuce by plasma processed tap water (PPtW) Up-scaling to industrial level.** Innov. Food Sci. Emerg. Technol. 53 (2019) 45-55; DOI:10.1016/j.ifset.2017.11.014

80. Schnabel, U.; Handorf, O.; Yarova, K.; Zessin, B.; Zechlin, S.; Sydow, D.; Zellmer, E.; Stachowiak, J.; Andrasch, M.; Below, H.; Ehlbeck, J.: **Plasma-Treated Air and Water-Assessment of Synergistic Antimicrobial Effects for Sanitation of Food Processing Surfaces and Environment.** Foods 8 (2019) 55; DOI:10.3390/foods8020055

81. Seebauer, C.; Bekeschus, S.; Schuster, M.; Hauschild, M.; Metelmann, H.-R.: **Wundmanagement - moderne Wundauflagen und Wundbehandlung in der MKG-Chirurgie.** MKG-Chirurg 12 (2019) 41-54; DOI:10.1007/s12285-018-0183-0

82. Semenov, I. L.; Weltmann, K.-D.; Loffhagen, D.: **Modelling of the transport phenomena for an atmospheric-pressure plasma jet in contact with liquid.** J. Phys. D: **Appl.** Phys. 52 (2019) 315203; DOI:10.1088/1361-6463/ab208e

83. Shekhar, R.; Gortschakow, S.; Grosshans, H.; Gerlach, U.; Uhrlandt, D.: **Numerical investigation of transient, low-power metal vapour discharges occurring in near limit ignitions of flammable gas, # J.** Phys. D: **Appl.** Phys. 52 (2019) 45202; DOI:10.1088/1361-6463/aaed04

84. Sheng, W.; Amin, I.; Neumann, C.; Dong, R.; Zhang, T.; Wegener, E.; Chen, W.-L.; Förster, P.; Tran, H. Q.; Löffler, M.; Winter, A.; Rodriguez, R. D.; Zschech, E.; Ober, C. K.; Feng, X.; Turchanin, A.; Jordan, R.: **Polymer Brushes on Hexagonal Boron Nitride.** Small 15 (2019) 1805228; DOI:10.1002/smll.201805228

85. Shi, F.; Steuer, A.; Zhuang, J.; Kolb, J. F.: **Bioimpedance Analysis of Epithelial Monolayers After Exposure to Nanosecond Pulsed Electric Fields.** IEEE Trans. Biomed. Eng. 66 (2019) 2010-2021; DOI:10.1109/TBME.2018.2882299

86. Shi, F.; Zhuang, J.; Kolb, J. F.: **Discrimination of Different Cell Monolayers before and after Exposure to Nanosecond Pulsed Electric Fields based on Cole-Cole and Multivariate Analysis.** J. Phys. D: **Appl.** Phys. 52 (2019) 495401; DOI:10.1088/1361-6463/ab40d7

87. Shim, H.; Lim, E.; Fleischmann, S.; Quade, A.; Tolosa, A.; Presser, V.: **Nanosized titanium niobium oxide/carbon electrodes for lithium-ion energy storage applications.** Sust. Energy Fuels 3 (2019) 1776-1789; DOI:10.1039/C9SE00166B

88. Sievers, G. W.; Anklam, K.; Henkel, R.; Hickmann, T.; Brüser, V.: **Corrosion-protection of moulded graphite conductive plastic bipolar plates in PEM electrolysis by plasma processing.** Int. J. Hydrogen Energy 44 (2019) 2435-2445; DOI:10.1016/j.ijhydene.2018.12.020

89. Sievers, G. W.; Bowen, J. R.; Brüser, V.; Arenz, M.: **Support-free nanostructured Pt-Cu electrocatalyst for the oxygen reduction reaction prepared by alternating magnetron sputtering.** J. Power Sources 413 (2019) 432-440; DOI:10.1016/j.jpowsour.2018.12.044

90. Sievers, G. W.; Jensen, A. W.; Brüser, V.; Arenz, M.; Escudero-escribano, M.: **Sputtered Platinum Thin-films for Oxygen Reduction in Gas Diffusion Electrodes: A Model System for Studies under Realistic Reaction Conditions.** Surfaces 2 (2019) 336-348; DOI:10.3390/surfaces2020025

91. Siewert, E.; Baeva, M.; Uhrlandt, D.: **The electric field and voltage of dc tungsten-inert gas arcs and their role in the bidirectional plasma-electrode interaction.** J. Phys. D: **Appl.** Phys. 52 (2019) 324006; DOI:10.1088/1361-6463/ab2325

92. Sigeneger, F.; Schäfer, J.; Foest, R.; Loffhagen, D.: **Phase-resolved modeling of a filamentary argon plasma in an RF plasma jet.** Plasma Sources Sci. Technol. 28 (2019) 55004; DOI:10.1088/1361-6595/ab1997

93. Stancu, E. C.; Quade, A.; Weltmann, K.-D.: **Polystyrene surface modification for serum-free cell culture using an atmospheric pressure dielectric barrier discharge Romanian.** Rep. Phys. 71 (2019) 409

94. Stancu, E. C.; Vizireanu, S.; Quade, A.; Stanciuc, A. M.; Moldovan, L.; Dinescu, G.: **Modification of Carbon Nanowalls Using Low Pressure Plasma to Enhance the Fibroblast Attachment Romanian J.** Phys. 64 (2019) 504

95. Striesow, J.; Lackmann, J.-W.; Ni, Z.; Wenske, S.; Weltmann, K.-D.; Fedorova, M.; v. Woedtke, T.; Wende, K.: **Oxidative modification of skin lipids by cold atmospheric plasma (CAP): A standardizable approach using RP-LC/MS2 and DI-ESI/MS2.** Chem. Phys. Lipids 223 (2019) 104786; DOI:10.1016/j.chemphyslip.2019.104786

96. Tarabov, B.; Luke, P.; Hammer, M. U.; Jablonowski, H.; von Woedtke, T.; Reuter, S.; Machalaa, Z.: **Fluorescence measurements of peroxynitrite/peroxynitrous acid in cold air plasma treated aqueous solutions.** Phys. Chem. Chem. Phys. 21 (2019) 8883-8896; DOI:10.1039/c9cp00871c

97. Teschner, T.; Bansemer, R.; Weltmann, K.-D.; Gerling, T.: **Investigation of Power Transmission of a Helium Plasma Jet to Different Dielectric Targets Considering Operating Modes.** Plasma 2 (2019) 348-359; DOI:10.3390/plasma2030027

98. von Woedtke, T.; Schmidt, A.; Bekeschus, S.; Wende, K.; Weltmann, K.-D.: **Plasma Medicine: A Field of Applied Redox Biology.** In Vivo 33 (2019) 1011-1026; DOI:10.21873/invivo.11570

99. Weiss, M.; Barz, J.; Ackermann, M.; Utz, R.; Ghoul, A.; Weltmann, K.-D.; Stope, M.B.; Wallwiener, D.; Schenke-Layland, K.; Oehr, C.; Brucker, S.; Loskill, P.: **Dose-Dependent Tissue-Level Characterization of a Medical Atmospheric Pressure Argon Plasma Jet.** ACS Appl. Mater. Interfaces 11 (2019) 19841-19853; DOI:10.1021/acsami.9b04803

100. Weltmann, K.-D.; Kolb, J. F.; Holub, M.; Uhrlandt, D.; imek, M.; Ostrikov, K.; Hamaguchi, S.; Cvelbar, U.; Cernk, M.; Locke, B.; Fridman, A.; Favia, P.; Becker, K.: **The future for plasma science and technology.** Plasma Process. Polym. 16 (2019) 1800118; DOI:10.1002/ppap.201800118

101. Wende, K.; v. Woedtke, T.; Weltmann, K.-D.; Bekeschus, S.: **Chemistry and biochemistry of cold physical plasma derived reactive species in liquids.** Biol. Chem. 400 (2019) 19-38; DOI:10.1515/hsz-2018-0242

102. Wenzel, T.; Berrio, D. A. C.; Daum, R.; Reisenauer, C.; Weltmann, K.-D.; Wallwiener, D.; Brucker, S. Y.; Schenke-Layland, K.; Brauchle, E.-M.; Weiss, M.: **Molecular Effects and Tissue Penetration Depth of Physical Plasma in Human Mucosa Analyzed by Contact- and Marker-Independent Raman Microspectroscopy.** ACS Appl. Mater. Interfaces 11 (2019) 42885-42895; DOI:10.1021/acsami.9b13221

103. Wetegrove M.; Witte K.; Bodnar W.; Pfahl D.-E.; Springer A.; Schell N.; Westphal F.; Burkel E.: **Formation of maghemite nanostructures in polyol: tuning the particle size via the precursor stoichiometry.** CrystEngComm 21 (2019) 1956-1966; DOI:10.1039/c8ce02115e

104. Zhang, G.; Goett, G.; Kozakov, R.; Uhrlandt, D.; Reisgen, U.; Willms, K.; Sharma, R.; Mann, S.; Lozano, P.: **Study of the arc voltage in gas metal arc welding.** J. Phys. D: **Appl.** Phys. 52 (2019) 85202; DOI:10.1088/1361-6463/aaf588

105. Zhang, G.; Goett, G.; Kozakov, R.; Uhrlandt, D.; Reisgen, U.; Willms, K.; Sharma, R.; Mann, S.; Lozano, P.: **Study of the wire resistance in gas metal arc welding.** J. Phys. D: **Appl.** Phys. 52 (2019) 85201; DOI:10.1088/1361-6463/aaf5bb

106. Zocher, K.; Lackmann, J.-W.; Volzke, J.; Steil, L.; Lalk, M.; Weltmann, K.-D.; Wende, K.; Kolb, J.: **Profiling microalgal protein extraction by microwave burst heating in comparison to spark plasma exposures.** Algal Res. 39 (2019) 101416; DOI:10.1016/j.algal.2019.101416

INVITED TALKS 2018

1. Gortschakow, S.; Franke, St.; Gött, G.; Kozakov, R.; Khakpour, A.; Methling, R.; Uhrlandt, D.: **Advanced optical diagnostics for characterisation of switching and welding arcs, ISPlasma**, Nagoya/Japan 2018

2. Pipa, A., Brandenburg, R.: **An equivalent circuit approach for the electrical diagnostics of dielectric barrier discharges, 29th Inter. Symp. on the Physics of Ionized Gases**, Belgrade/Serbia 2018

3. Brüser, V.; Peglow, S.; von Woedtke, T.: **Applications of Plasma Technology for Nano Structured Material Synthesis and Medical Engeneering, Sakharov Readings 2018: Environmental Problems of the XXI Century**, Minsk/Belarus 2018

4. Uhrlandt, D.; Zhang, G.; Gött, G.; Baeva, M.; Gorschakow, S.: **Arc electrode interaction in thermal plasma application, 15th International High Tech Plasma Processes Conference**, Toulouse/France 2018

5. Hasse, S.; Seebauer, C.; Masur, K.; Segebarth, M.; Bekeschus, S.; von Woedtke, T.; Metelmann, H.-R.: **Cold atmospheric plasma for the treatment of intraoral (precancerous) lesions - in vitro and in vivo investigations, 8th International Symposium on Plasma Biosciences**, Seoul/Korea 2018

6. Seebauer, C.; Hasse, S.; Segebarth, M. ; Bekeschus, S.; von Woedtke, T.; Weltmann, K.-D.; Schuster, M.; Rutkowski, R.; Metelmann, H.-R.: **Cold Atmospheric Plasma for the treatment of oral lichen planus as intraoral precancerous lesion, 5th International Workshop on Plasma for Cancer Treatment**, Greifswald/Deutschland 2018

7. Uhrlandt, D. **Current Interruption Principles**, ICGS Winter School, Chennai/India 2018

8. Weltmann, K.-D.: **Development of plasma sources for medical applications, ISPlasma**, Nagoya/Japan 2018

9. Weltmann, K.-D.; von Woedtke, T.; Gerling, T.: **Development of plasma sources for Plasma Medicine, clinical results and future applications, 5th International Workshop Plasma Science and Interfaces**, St. Gallen/Schweiz 2018

10. Brandenburg, R.; Jahanbakhsh, S.; Kettlitz, M.; Höft, H.; Schmidt, M.; Schiorlin, M.: **Dielectric Barrier Discharges as Tools for Air Cleaning, 11th Intern. Symp. on Non-Thermal/Thermal Plasma Pollution Control Technology Sustainable Energy**, Montegrotto Terme/Italy 2018

11. Masur, K.; Urubschurov, V.; Shome, D.; von Woedtke, T.; Metelmann, H.R.; Motz, W.; Weltmann, K.-D.: **Influence of Cold Atmospheric Pressure Plasma on Wound Healing, 8th International Symposium on Plasma Biosciences**, Seoul/Korea 2018

12. Lang, N.; Puth, A. D. F.; Klose, S.-J.; Kowzan, G.; Hamman, S.; Röpcke, J.; Maslowski, P.; van Helden, J. H.: **Mid-infrared frequency comb spectroscopy for plasma-surface interaction studies, Gordon Research Conference Plasma Processing Science**, Smithfield/USA 2018

13. Kolb, J. F.; Brust, H.; Wannicke, N.; Ehlbeck, J.; Schnabel, U.; von Woedtke, Th.; Weltmann, K. D.: **Non-thermal Plasmas for Post-harvest Preservation of Fruits and Vegetables and Pre-sowing Preparation of Seeds, 2nd International Workshop on Plasma Agriculture**, Takayama/Japan

14. Kolb, J.F.; Brust, H.; Wannicke, N.; Nishime, T.; Zocher, K.; Ehlbeck, J.; Schnabel, U.; von Woedtke, Th., Weltmann, K. D.: **Non-thermal Plasmas for Pre- and Post-harvest Processing of Seeds and Crops, 15th International Bioelectrics Symposium**, Prague/Czech Republic 2018

15. Schmidt, A.; von Woedtke, T.; Vollmar, B.; Hasse, S.; Bekeschus, S.: **Nrf2 signaling and inflammation are key events in physical plasma-spurred wound healing, 8th International Symposium on Plasma Biosciences**, Seoul/Korea 2018

16. Fricke, K.: **Oberflächengestaltung von Implantaten mittels Plasmatechnologie, MedTech Summit**, Nürnberg/Germany 2018

17. Klose, S.-J.; Gianella, M.; Reuter, S.; Press, S.; Aguila, A. L.; Manfred, K.; Schmidt-Bleker, A.; Ritchie, G. A. D.; van Helden, J. H.: **On the chemical kinetics of HO2 in a cold atmospheric plasma jet, 8th IPS**, Oxford/UK 2018

18. Weltmann, K.-D.; Methling, R.; Götte, N.; Wetzeler, S.; Uhrlandt, D.: **Optical Emission Spectroscopy of Ablation-Dominated Arcs during High-Current Phase and around Current Zero, 22nd Int. Conf. on Gas Discharges and their Applications**, Novi Sad/Serbia 2018

19. Weltmann, K.-D.; Brust, H.; Ehlbeck, J.; Reuter, S.; Schnabel, U.; von Woedtke, T.; Wannicke, N.; Kolb, J. F.: **Overview of plasma applications in agriculture in Germany and the EU, 2nd International Workshop on Plasma Agriculture**, Takayama/Japan

20. Sigeneger, F.; Schäfer, J.; Foest, R.; Loffhagen, D.: **Phase-resolved modelling of a non-thermal atmospheric pressure RF plasma jet, 24th ESCAMPIG**, Glasgow/UK 2018

21. Weltmann, K.-D.; Brust, H.; Reuter, S.; von Woedtke, T.; Wannicke, N.; Kolb, J. F.: **Plasma applications in agriculture the next new field of research, 7th International Conference on Plasma Medicine**, Philadelphia/USA 2018

22. von Woedtke, T.; Metelmann, H.-R.; Weltmann, K.-D.: **Plasma in cosmetic applications: possibilities and boundary conditions, 8th International Symposium on Plasma Biosciences**, Seoul/Korea 2018

23. von Woedtke, T.: **Plasma medicine: innovative physics for medical applications, 8th International Conference on Oxidative Stress in Skin Biology and Medicine**, Andros/Greece 2018

24. Weltmann, K.-D.: **Plasma medicine: State research, development, devices, therapy and perspectives, Satellite Workshop of ISPlasma**, Nagoya/Japan 2018

25. Uhrlandt, D.; Kolb, J.: **Plasma processes for water cleaning, ICGS Winter School**, Chennai/India 2018

26. Kolb, J.F.; Schnabel, U.; Ehlbeck, J.; Brust, H.; Wannicke, N.; Weltmann, K. D.: **Plasmas for Agriculture: Pre-Harvest Preparation and Post-Harvest Preservation, 45th ICOPS**, Denver/USA 2018

27. Lang, N.; Puth, A. D. F.; Kowzan, G.; Hamman, S.; Röpcke, J.; Maslowski, P.; van Helden, J. H.: **Plasma-surface interaction studies: Development and application of advanced laser-based diagnostics, 45th European Physical Society Conference on Plasma Physics**, Prague/Czech Republic 2018

28. Kolb, J. F.; Ehlbeck, J.; Zocher, K.; Schnabel, U.; Andrasch, M.; Brust. H,; Wannicke, N.; von Woedtke, Th.; Weltmann, K. D.: **Post-harvest processing of crops by plasma and pulsed electric fields, ISPlasma**, Nagoya/Japan 2018

29. Harhausen, J.: **Prospects for the enhancement of PIAD processes by monitoring of optical thickness and plasma parameters, DPG Frühjahrstagung Plasmaphysik**, Erlangen/Deutschland 2018

30. Kolb, J. F.; Kredl. J.; Schulz, T.; Ratay, R.; Hahn, V.; Schmidt, M.; Weltmann, K. D.: **Pulsed Discharges in and close to Water for Degradation of Microbiological and Chemical Contaminants, 45th ICOPS**, Denver/USA 2018

31. Weltmann, K.-D.; Gerling, T.; Hahn, V.; Masur, K.; Metelmann, H.-R.; von Woedtke, T.: **Research and development of plasma sources for applications in life science, 8th International Symposium on Plasma Biosciences**, Seoul/Korea 2018

32. Weltmann, K.-D.: **Standards of Non-thermal Biocompatible Plasma (NBP) sources and its applications in Plasma Medicine, 8th International Symposium on Plasma Biosciences**, Seoul/Korea 2018

33. Weltmann, K.-D.: **Views and Visions of Plasma Medicine in Cancer Treatment, 5th International Workshop on Plasma for Cancer Treatment**, Greifswald/Deutschland 2018

34. Wende, K.: **When chemistry meets biology plasmas in medicine, 7th International Conference on Plasma Medicine**, Philadelphia/USA 2018

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5. Kolb, J. F.; Steuer, A.; Wolff, C. M.; Shi, F.; Schmidt, A.; Wende, K.; Wei, W.; Bekeschus, S.; Villardell-Scholten, L.; Gerling, T.; von Woedtke, T.: **Collective manipulation of cells in monolayers by pulsed electric fields and non-thermal plasma, WCElectroporation, Tolouse, 2019, 3rd World Congress on Electroporation**, Toulouse/France 2019

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21. Wannicke, N.; Brust , H.; Nishime, T.; Horn, S.; Timm, M.; Wagner, R.; Bousselmi, S.; Balazinzki, M.; Kolb, J.F.; Weltmann, K.-D.: **Plasma application in agriculture, German-Polish Networks for the Environment - Innovative Projects for the Future**, Warsaw/Poland 2019

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37. Brandenburg, R.; Jahanbakhsh, S.: **Time-correlated single photon counting on transient plasmas at atmospheric pressure, FLTPD XIII**, Bad Honnef/Deutschland 2019

38. von Woedtke, T. **Translation from plasma medicine achievements to cosmetics**, International Meeting on Plasma Cosmetic Science, Orleans/France 2019

39. Brandenburg, R.: **Tutorial: Atmospheric Pressure Plasmas, DPG Frühjahrstagung Kondensierte Materie**, Regensburg/Deutschland 2019

40. Schmidt-Bleker, A.: **UV spectroscopy on plasma treated liquids, 19. Fachtagung für Plasmatechnologie**, Cottbus/Germany 2019

41. von Woedtke, T: **Worauf beruht die wissenschaftliche Evidenz der plasmaunterstützten Wundheilung?, Deutscher Wundkongress**, Bremen/Deutschland 2019

42. von Woedtke, T; Metelmann, H-R.; Emmert, S.; Weltmann, K-D.: **Wound treatment by cold atmospheric plasma: what evidence do we have?, 9th Int. Symp. for Plasma Biosciences**, Gangneung City/South Korea 2019

43. Gött, G.; Uhrlandt, D.: **Zur Untersuchung von Schweisslichtbögen und ihres Potentials für die Prozesskontrolle, 19. Fachtagung für Plasmatechnologie**, Cottbus/Germany 2019

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PATENTS 2018

Patents applied

1. Polak, M.; Hempel, F.; Garkas, W.; Weltmann, K.-D.: Antibacterial Surface Modification for Medical Devices, EP 181597931, angemeldet: 02.03.2018

2. Uhrlandt, D.; Gött, G.; Steusloff, R.; Ruh, D.: Berührungsloses Temperaturmessverfahren und berührungsloses Temperaturüberwachungsverfahren zum Ermitteln einer Temperatur während einer Wärmebehandlung eines Werkstücks, Wärmebehandlung eines Werkstücks und Gerät für eine berührungslose Temperaturmessung, DE 1020181137850, angemeldet: 08.06.2018

3. Schmidt-Bleker, A.; Winter, J.; Weltmann, K.-D.; Bendt, H.: Desinfektionsverfahren mit einem durch Reaktion von H2O2 und NO2 in situ gebildetem Desinfektionswirkstoff, PCT/EP2018/063226, angemeldet: 18.05.2018

4. Brüser, V.; Reuter, S.; Rossow, N.: Device and method for chemo-physical modification of particles of a suspension, EP 181865379, angemeldet: 31.07.2018

5. Weltmann, K.-D.; von Woedtke, T.; Stieber, M.; Horn, S.: Device, system, and method for antimicrobial treatment, method for manufacturing the device and computer program, JP 2018-548128, angemeldet: 25.09.2018

6. Weltmann, K.-D.; von Woedtke, T.; Stieber, M.; Horn, S.: Device, system, and method for antimicrobial treatment, method for manufacturing the device and computer program, US 16/085,580, angemeldet: 16.09.2018

7. Weltmann, K.-D.; Schmidt-Bleker, A.: Method and Apparatus for Generating a Product Gas Stream, US 16/095,367, angemeldet: 21.10.2018

8. Schmidt-Bleker, A.; Winter, J.; Weltmann , K.-D.: Modular plasma jet treatment system, KR 10-2018-0121069, angemeldet: 11.10.2018

9. Schmidt-Bleker, A.; Winter, J.; Weltmann, K.-D.: Modular plasma jet treatment system, US 16/161,680, angemeldet: 16.10.2018

10. Weltmann, K.-D.; Stieber, M.; Horn, S.; von Woedtke, T.; Brandenburg, R.; Turski, P.: System and Method for Treating Surfaces of Bodies, In Particular For Wound Treatment, US 16/090,228, angemeldet: 31.10.2018

11. Weltmann, K.-D.; Stieber, M.; Horn, S.; von Woedtke, T.; Brandenburg, R.; Turski, P.: System und Verfahren zur Behandlung von Oberflächen von Körpern, insbesondere zur Wundbehandlung, EP 177141942, angemeldet: 30.10.2018

12. Ehlbeck, J.; Andrasch, M.; Stachowiak, J.; Schnabel, U.; Krohmann, U.; Bösel, A.: Verfahren, Plasmazündeinrichtung und System zur biologischen Dekontamination, Desinfektion oder Sterilisation von Behandlungsgut mittels eines Reaktivgases, EP 181605676, angemeldet: 07.03.2018

13. Weltmann, K.-D.; Schmidt-Bleker, A.: Verfahren und Vorrichtung zur Erzeugung eines Produktgasstroms, EP 177192366, angemeldet: 16.11.2018

14. Weltmann, K.-D.; Schmidt-Bleker, A.: Verfahren und Vorrichtung zur Erzeugung eines Produktgasstroms, KR 10-2018-7033603, angemeldet: 20.11.2018

15. Weltmann, K.-D.; von Woedtke, T.; Stieber, M.; Horn, S.: Vorrichtung, System und Verfahren zur antimikrobiellen Behandlung, Verfahren zur Herstellung der Vorrichtung und Computerprogramm, EP 177129434, angemeldet: 16.10.2018

16. Weltmann, K.-D.; Brandenburg, R.; Stieber, M.; Horn, S.; Schmidt, M.; von Woedtke, T.; Winter, J.: Vorrichtung zur plasmagestützten Behandlung von Flüssigkeiten, EP 181688144, angemeldet: 23.04.2018

Patents filed granted

17. Weltmann, K.-D.; von Woedtke, T.; Stieber, M.; Krömker, W.: Hand Disinfection Device Having a Plasma and Aerosol Generator, US10,124,080B2, erteilt: 13.11.2018

18. Ehlbeck, J.; Stieber, M.; Weltmann, K.-D.: Method and Device for Plasma-Treating Hollow Bodies, US 9,855,355 B2, erteilt: 02.01.2018

19. Weltmann, K.-D.; Gerling, T.; Lembke, N.: Plasmabehandlungsgerät, EP3051927 B1, erteilt: 28.02.2018

20. Ehlbeck, J.; Krohmann, U.; Lehmann, W.; Neumann, T.; Weltmann, K.-D.; Andrasch, M.; Schnabel, U.: Plasma-Generated Gas Sterilization Method and Device, US 10,039,849 B2, erteilt: 07.08.2018

21. Stieber, M.; Mahrenholz, C.; Güra, T.; Krafczyk, S.; von Woedtke, T.; Weltmann, K.-D.; Bussiahn, R.; Horn, S.; Brandenburg, R.: Device for generating a cold atmospheric pressure plasma, ZA 2017/02424, erteilt: 28.03.2018

PATENTS 2019

Patents applied

1. Gött, G.; Uhrlandt, D.; Ruh, D.; Steusloff, R.: Berührungsloses Temperaturmessverfahren und berührungsloses Temperaturüberwachungsverfahren zum Ermitteln einer Temperatur während einer Wärmebehandlung eines Werkstücks, Wärmebehandlung eines Werkstücks und Gerät für eine berührungslose Temperaturmessung , EP 190203646, angemeldet: 06.06.2019

2. Schmidt-Bleker, A.; Winter, J.; Bendt, H.; Weltmann, K.-D.: Desinfektionsverfahren mit einem durch Reaktion von H2O2 und NO2 in situ gebildetem Desinfektionswirkstoff, PCT/EP2019/062897, angemeldet: 17.05.2019

3. Schmidt-Bleker, A.; Winter, J.; Weltmann, K.-D.: Desinfektionsverfahren mit einem durch Reaktion von H2O2 und NO2 in situ gebildetem Desinfektionswirkstoff mit retardierter Wirkstofffreisetzung, EP 191954593, angemeldet: 04.09.2019

4. Winter, J.: Device and method for generating a plasmajet, EP 177496635, angemeldet: 02.04.2019

5. Winter, J. Device and method for generating a plasmajet:, US 16/330,090, angemeldet: 03.03.2019

6. Brandenburg, R.; Horn, S.; Stieber, M.; Weltmann, K.-D.; von Woedtke, T.: Device for the Planar Treatment of Areas of Human or Animal Skin or Mucous Membrane Surfaces by Means of a Cold Atmospheric Pressure Plasma, US 16/285,254, angemeldet: 26.02.2019

7. Weltmann, K.-D.; Stieber, M.; Brandenburg, R.; Horn, S.; Schmidt, M.; Winter, J.; von Woedtke, T.: Device for the Plasma-Supported Treatment of Liquids, US 16/391,459, angemeldet: 23.04.2019

8. Bekeschus, S.; Poschkamp, B.: Methode zur Klassifikation von Thrombozyten-Aggregationen, EP 192041135, angemeldet: 18.10.2019

9. Brandenburg, R.; Foest, R.; Pipa, A.; Hink, R.; Caspari, R.; Weichwald, R.; Schreiner, R.; Lindner, M.; Berndt, D.: Strömungsfläche eines Fahrzeugs mit einer Enteisungsvorrichtung zum Entfernen oder Verhindern eines Eisansatzes an der Strömungsfläche, DE 1020190033264, angemeldet: 13.05.2019

10. Turski, P.; Lembke, N.; Gerling, T.; Vilardell Scholten, L.; Horn, S.; Kohls, R.; Weltmann, K.-D.: System und Verfahren zum Betrieb einer Plasmajetkonfiguration, EP 192014959, angemeldet: 04.10.2019

Patents filed granted

11. Weltmann, K.-D.; Brandenburg, R.; Stieber, M.; Horn, S.; Turski, P.: Device for generating plasma, system for generating plasma and method for generating plasma, US 10,307,606 B2, erteilt: 04.06.2019

12. Brandenburg, R.; Horn, S.; Stieber, M.; Weltmann, K.-D.; von Woedtke, T.: Device for the Planar Treatment of Areas of Human or Animal Skin or Mucous Membrane Surfaces by Means of a Cold Atmospheric Pressure Plasma, US 10,265,116 B2, erteilt: 23.04.2019

13. Weltmann, K.-D.; Brandenburg, R.; Krafczyk, S.; Stieber, M.; von Woedtke, T.: Device for the Plasma Treatment of Human, Animal or Plant Surfaces. in Particular of Skin or Mucous Membrane Areas, US 10,363,429 B2, erteilt: 30.07.2019

14. Stieber, M.; Ehlbeck, J.; Stachowiak, J.: Device, system, and method for treatment of an object with plasma, US 10,283,323 B2, erteilt: 07.05.2019

15. Kolb, J.; Weltmann, K.-D.; Banaschik, R.; Zhuang, J.: Einrichtung zur Behandlung von Fluiden in Form von Trinkwasser, Brauchwasser, Abwasser oder wässrigen Lösungen durch Erzeugung von Koronaentladungen in einem Fluidvolumen, EP 3003988 B1, erteilt: 04.12.2019

16. Schmidt-Bleker, A.; Reuter, S.; Weltmann, K.-D.: Verfahren und Vorrichtung zum Erzeugen eines kalten Plasmas mit einer ersten und einer zweiten Kammer, EP 3016483 B1, erteilt: 01.05.2019

17. Brüser, V.; Kruth, A.; Sievers, G.; Walter, C.; Jakubith, S.; Steffen, F.: Verfahren zur Herstellung von Gasdiffusionselektroden für Brennstoffzelle, sowie Gasdiffusionselektrode und Brennstoffzelle, EP3161889 B1, erteilt: 21.08.2019

18. Weltmann, K.-D.; von Woedtke, T.; Lademann, O.: Vorrichtung zur Behandlung von lebenden Zellen mittels eines Plasmas, EP 2465332 B1, erteilt: 20.11.2019

19. Brandenburg, R.; Horn, S.; Stieber, M.; von Woedtke, T.; Weltmann, K.-D.: Vorrichtung zur flächigen Behandlung von Bereichen menschlicher oder tierischer Haut- bzw. Schleimhautoberflächen mittels eines kalten Atmosphärendruckplasmas, EP 2471348 B1, erteilt: 16.10.2019

Bachelor

1. Barthel, Niklas (Bachelor, Universität Greifswald, 22.02.2019)
   TOC-Gehalt von Abwasser vor und nach Plasmabehandlung

2. Goeltenbott, Thomas (Bachelor, Hochschule München, Werkstofftechnik, 01.11.2019)
   Diffusionsgesteuerte Auflösungscharakteristik von Wolframcarbiden in eisenbasierten Matrizes

3. Monge, Stefanie (Bachelor, Staatliche Universität Cartago, Costa Rica, 04.12.2019)
   Effects of Plasma Treated Water on Germination and Growth of Cereals and Legumes

4. Poschkamp, Broder (Bachelor, Universität Greifswald, 27.09.2019)
   Convolutional Neural Networks für einen Image Cytometry-basierten Thrombozytenfunktionstest

5. Scheuffler, Caroline (Bachelor, Universität Rostock, 25.10.2019)
   Etablierung eines Coating Prozesses mit bioaktiven Glas für additiv gefertigte, piezoelektrische Kompositkeramiken

6. Schmidt, Jan (Bachelor, Hochschule Stralsund, 10.07.2019)
   Vergleich zweier Signalerzeugungskonzepte zum Betrieb einer dielektrisch behinderten Entladung in Argon

7. Tomasi, Gianluca (Bachelor, Hochschule Stralsund, 02.09.2019)
   Untersuchungen an Plasmaelektroden für elektrochemische Zellen mit oxidionenleitenden Festelektrolyten

8. Winter, H (Bachelor, Universität Greifswald, 22.12.2019)
   Einfluss von physikalischem Plasma auf das Proteom- und Antibiotikaresistenzprofil eines Abwasserisolates

Master

1. Destrieux, A. (Master, P. Universität Paul Sabatier Toulouse, 01.07.2019)
   Caractrisationlectrique et optique d'une dcharge barrire dilectrique

2. Lippert, Maxi (Master, Universität Greifswald, 30.04.2019)
   Determinanten des oxidativen Zelltodes in THP-1 und Jurkat Zellen

3. Panciera, Guido (Master, University of Bologna, 21.09.2019)
   Investigation on the influence of different dielectric materials on capacitively coupled plasma jet behaviour

4. Pogoda, Alexander (Master, Universität Greifswald, 16.04.2019)
   Etablierung absorptionsspektrometrischer Methoden zur Untersuchung einer aerosolbetriebenen Plasmaquelle

5. Wagner, Robert (Master, Universität Greifswald, 02.12.2019)
   Object Detection of Seed Germination Using Convolutional Neural Networks

Promotion

1. Bethge, L. (Promotion, Universität Greifswald, 25.04.2019)
   Stimulation der Immunantwort von humanen THP-1 Monozyten und Einfluss auf das Kulturmedium durch Behandlung mit dem kalten Atmosphärendruck-Plasmajet kINPenMed unter besonderer Berücksichtigung der Umgebungsparameter

2. Nishime, Thalita (Promotion, Sao Paulo State University, 16.10.2019)
   Development and characterization of extended and flexible plasma jets

3. Tran, TD. (Promotion, Universitätsmedizin Greifswald, 18.07.2019)
   Ex-vivo-Untersuchung zum Einfluss der Plasmabehandlung von menschlicher Haut mittels Atmosphärendruck-Plasmajet kINPen MED auf molekularer Ebene

4. Tyl, Clemence (Promotion, Universität Paul Sabatier Toulouse, 18.12.2019)
   Study of the memory effect in Atmospheric Pressure Townsend Discharges in nitrogen with addition of oxidizing gas

5. Zocher, Katja (Promotion, Universität Greifswald, 03.12.2019)
   Extraktion of valuable compounds from micro-algae by plasma technologies

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