BIENNIAL REPORT 2014/2015

LEIBNIZ INSTITUTE FOR PLASMA SCIENCE AND TECHNOLOGY

INP Greifswald

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welcome@inp-greifswald.de

Dear Sirs and Mesdames,

The Leibniz-Institute for Plasma Science and Technology (INP) belongs to the leading European centers in the field of application-oriented basic research on low-temperature plasmas and their technological applications, based on a combination of excellent knowledge-oriented basic research and application-oriented industrial feasibility.

Since 2003, the number of employees of our institute has nearly tripled, the industry funds have risen at least tenfold and about 60 projects were acquired per year. This success is due to the continuous adaptation of the institute strategy according to changing external and internal conditions. Within the last two years, therefore two major research directions have been established: The research division "Plasmas for Materials and Energy" performs complementary research in the field of plasma technology, plasma material processing and electrical engineering. Apart from that the research division "Plasmas for Environment and Health" deals with interdisciplinary and translational projects within the field of life science.

At our institute physicists, mathematicians, chemists, biologists, engineers and pharmacists work together closely to gain a better understanding of the complex processes within the plasma research in interdisciplinary topics.

On this basis and due to its excellent facilities the INP was able to open up new fields of applications in plasma technology such as plasma medicine, decontamination and electrical engineering. In parallel, the number of scientific publications raised, which in turn strengthened the international visibility. For securing this high level of research further training of young academics is of high priority for the INP Greifswald.

We received an outstanding confirmation of the institutes' effort during the last evaluation. The external evaluation committee visited our institute in 2014 and stated in their final report:
"Since the last evaluation, INP has been remarkably successful in continuing its strategic development. There is great potential for further significant advances in the coming years."

This remark made us proud of our achievements and let us look ahead highly motivated. On that note, I would like to thank all the stakeholders and especially the employees of INP for your extraordinary commitment and continued support.

I wish you an interesting and inspiring reading of our biennial report and I would be pleased to arouse your curiosity about our institute.

With best wishes

Prof. Dr. Klaus-Dieter Weltmann
Director

CONTENT

CONTENT

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

GOOD SCIENTIFIC PRACTICE

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

STRATEGY

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

EQUAL OPPORTUNITIES

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

COMMUNICATION AND TEAM PLAY

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

JUNIOR STAFF DEVELOPMENT

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

INTERNATIONALIZATION

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

TRANSFER OF RESEARCH RESULTS

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

Total E-Quality Certificate awarded in 2014

The Leibniz Institute of Plasma Science and Technology has been awarded the TOTAL E-QUALITY certificate for 2014 to 2016 for its vital institute culture of equal opportunities. The certificate is awarded by the TOTAL E-QUALITY Deutschland e. V.

The jury stated: "The Leibniz Institute of Plasma Science and Technology is actively engaged in establishing gender equality for women and men and creates family-friendly working conditions to attract the best scientists of their speciality and to retain them for the institute with their scientific potential for the long term." And furthermore: "To raise the proportion of woman especially at the managerial level poses a huge challenge for the institute with its scientific and engineering profile combined with specific site and economic conditions." The INP Greifswald further pursues that aim with strong commitment and therefore involves the good cooperating local colleges and universities.

The certificate has been developed by means of the Federal Ministry of Education and Research and the European Union and is awarded for acting in an exemplary manner for a personnel policy oriented towards equal opportunities.

The association TOTAL-E-QUALITY Deutschland e. V.

Since 1996, TOTAL E-QUALITY Deutschland e. V. has been aiming to establish and sustainably ensure equal opportunities. This aim is achieved when talents, capabilities and expertise of both genders are recognized, embraced and promoted in equal measures. TOTAL E-QUALITY Management (stands for Total Quality Management and Equality) is a human resources management, oriented on the one hand at the gender and on the other at the very differing life-events of the employees. One of the key issues is the advancement of women in leadership positions. In addition to the reconciliation of work and family life, TOTAL E-QUALITY is also concerned with equal opportunities in personnel recruitment and development, the promotion of fair behaviour at the workplace and the consideration of equal opportunity in the company principles.

The TOTAL E-QUALITY Award is presented each year for exemplary activities in terms of human resource management aimed at providing equal opportunity. The award certifies that the recipient has shown a successful and sustained commitment to equal opportunities for women and men in the professions. *www.total-e-quality.de*

In 2017 the INP will apply with an update for that certificate to be prolonged until 2019.

TOTAL E-QUALITY

General information

The Leibniz Institute for Plasma Science and Technology (INP Greifswald) conducts application-oriented basic research in the fields of low-temperature plasmas and plasma technologies within the Research Division Plasmas for Materials and Energy and the Research Division Plasmas for Environment and Health. The research is closely linked to the promotion of new applications that can be brought to market with the Institute's own transfer center.

INP Greifswald e. V. is a member of the Gottfried Wilhelm Leibniz Association (WGL). The institutes of the Leibniz Association are independent scientific research institutes that are financed jointly by the German Federal Government and the federal states, as well as by independently raised third-party funds.

In its efforts, INP takes into account both: requirements in research and development as well as market needs in industry. The Institute has distinguished expertise and know-how for the realization of modern plasma applications and dedicates this competence to the research of socially relevant topics where plasma could offer solutions.

True to INPs motto „From idea to prototype", basic research is closely connected with the development of new applications. On one hand, innovative approaches are pursued until there is proof of technical feasibility. On the other hand, current problems in plasma technology serve for orientation and driving force for the pursuit of knowledge on the fundamental questions in plasma physics.

Core expertise

Scientific Departments:

- Plasma Surface Technology
- Plasma Process Technology
- Plasma Radiation Techniques
- Plasma Diagnostics
- Plasma Sources
- Plasma Bioengineering
- Plasma Modelling
- Plasma Life Science

Research Division Plasmas for Materials and Energy

- Research Programm Surfaces and Materials
- Research Programm Process Monitoring
- Research Programm Welding and Switching

Research Division Plasmas for Environment and Health

- Research Programm Bioactive Surfaces
- Research Programm Plasma Medicine
- Research Programm Decontamination

Board of Trustees

The Board of Trustees is the supervisory body of INP including representatives from the State of Mecklenburg-Vorpommern and the Federal Republic of Germany. The Board decides on all essential scientific, economic and organizational issues of INP.

Members (Status 2015)

RDin Nicole Kraheck (Chair)
Federal Ministry of Education and Research

Woldemar Venohr (Deputy Chair)
Ministry of Education, Science and Culture,
Mecklenburg-Vorpommern

Prof. Dr. Wolfgang Schareck
University of Rostock

Prof. Dr. med. Wolfgang Motz
Karlsburg Clinic

Dr. Helmut Goldmann
Aesculap AG

Dr. Edgar Dullni
ABB AG

Scientific Advisory Council

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

Members (Status 2015)

Prof. Dr. Thomas Klinger (Chair)
Max Planck Institute for Plasma Physics
Greifswald

Prof. Dr. Kurt Becker (Deputy Chair)
Polytechnic Institute of New York University

Dr. Uwe Kaltenborn
Maschinenfabrik Reinhausen GmbH, Regensburg

Prof. Dr.-Ing. Peter Awakowicz
Ruhr-Universität Bochum (RUB)

Prof. Dr. Holger Kersten
Christian Albrechts Universität Kiel (CAU)

Prof. Dr. Jürgen Meichsner
Ernst Moritz Arndt University of Greifswald

Prof. Dr. Kerstin Thurow
Center for Life Science Automation, Rostock

Ernst Miklos
The Linde Group, Unterschleißheim

Prof. Dr. Dr.-Ing. Jürgen Lademann
Charité – Universitätsmedizin Berlin

Dr. Jean-Michele Pouvesle
Université d'Orleans

General Assembly

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

Members (Status 2015)

Dr. Wolfgang Blank (Chair)
BioTechnikum Greifswald GmbH

RDin Nicole Kraheck
Federal Ministry of Education and Research

Woldemar Venohr
Ministry of Education, Science and Culture,
Mecklenburg-Vorpommern

Prof. Dr. Dagmar Braun
Braun Beteiligungs GmbH, Greifswald

Prof. Dr. Holger Fehske
Ernst Moritz Arndt University of Greifswald

Dr. Stefan Fassbinder
Major University and Hanseatic City of Greifswald

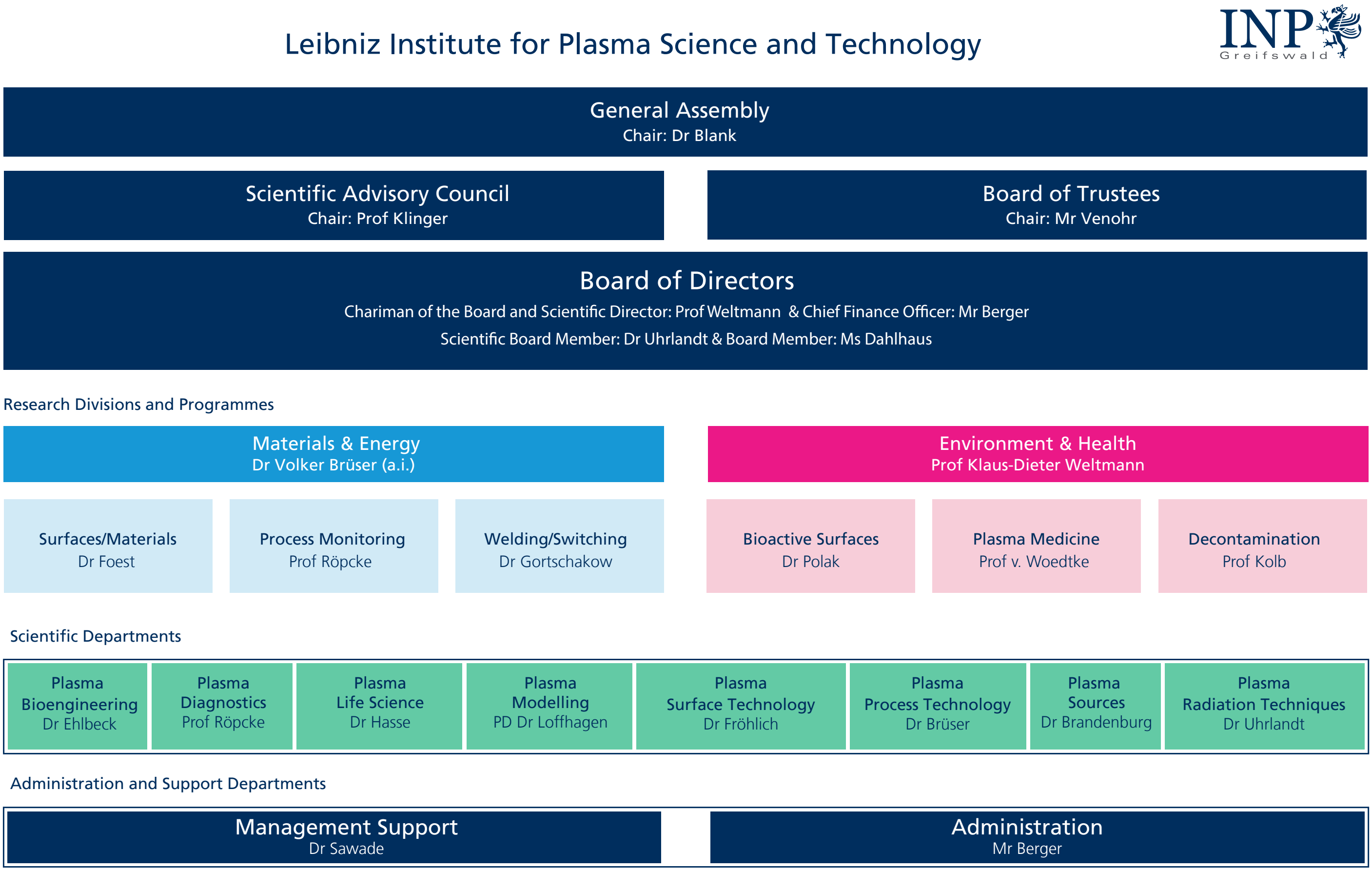
Mario Kokowsky
DEN GmbH

Dr. Ulrich Kogelschatz
Formerly at ABB AG

Prof. Dr. Jürgen Meichsner
Ernst Moritz Arndt University of Greifswald

Prof. Dr. Rolf Winkler
Formerly at Leibniz Institute for Plasma Science
and Technology e. V.

Dr. Arthur König
Formerly Major University and Hanseatic City
of Greifswald

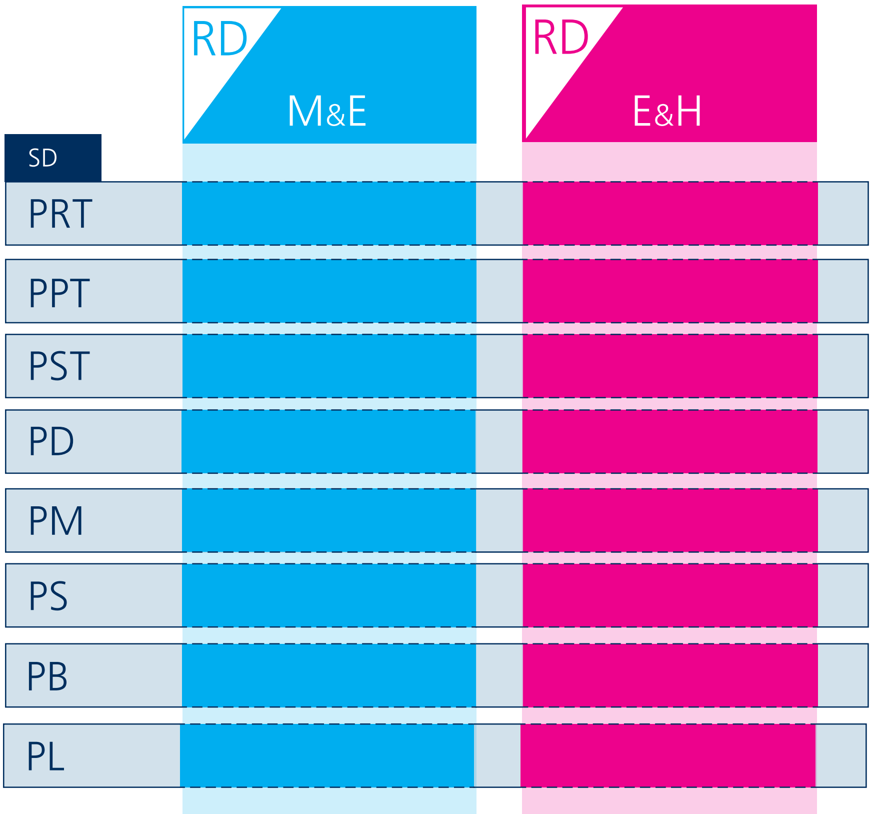


Organizational chart
of the INP Greifswald (2016).

Organizational structure

Since 2004, the Institute has adopted a matrix structure. This is to improve the implementation of the described guiding principle linking fundamental research and applications. In addition an efficient and flexible exchange across different Research Programmes is facilitated.

As shown in the organization chart, INP is scientifically divided into two Research Divisions: “Plasmas for Materials and Energy” and “Plasmas for Environment and Health”. Currently each Research Division encompasses four Research Programmes. The Research Programmes are based on particularly attractive, application-oriented scientific issues at the present time and form the core of INP’s scientific work.



Matrix structure of the Research Divisions (RD) and Scientific Departments (SD)

Research Divisions Plasmas for Materials & Energy (RD M&E)

- Research Programme Surfaces and Materials
- Research Programme Process Monitoring
- Research Programme Welding and Switching

Research Divisions Plasmas for Environment & Health (RD E&H)

- Research Programme Bioactive Surfaces
- Research Programme Plasma Medicine
- Research Programme Decontamination

Scientific Departments (SD)

- Plasma Radiation Techniques (PRT)
- Plasma Process Technology (PPT)
- Plasma Surface Technology (PST)
- Plasma Diagnostics (PD)
- Plasma Modelling (PM)
- Plasma Sources (PS)
- Plasma Bioengineering (PB)
- Plasma Life Science (PL)

Services and infrastructure of INP

The Institute's motto – From idea to prototype – not only describes the application-oriented basic research approach, but also the intended transfer of research results. The INP Greifswald drive the application process with industry-oriented research and technology transfer. In order to transfer technology, INP became the first Leibniz institute to establish its own company, neoplas GmbH.
www.neoplas.eu

INP Greifswald e. V. has modern laboratories with excellent and partially unique equipment for the analysis of plasma processes and plasma sources, plasma-treated surfaces and special plasma applications such as biomedical applications and arc plasmas in switch gear and for cutting and welding. The equipment can be made available to external users and can partially be used for research on-site. Those special application laboratories translate research results into practical functional models and demonstration objects as active intersections between science and industry:

Plasma diagnostics laboratory

Application and further development of different methods of plasma diagnostics:

- Absorption spectroscopy in the UV-VIS mid-infrared range
- Quantum cascade laser (QCL) spectroscopy for plasma monitoring
- Laser-induced fluorescence (LIF)
- Probe measurements
- Mass spectrometry
- Optical Emission Spectroscopy (OES in the UV-VIS range)

Laboratory for surface diagnostics

By using plasma technology it is possible to specifically modify surface property and to generate new materials with special functions. Surface analyses are a specialty of INP:

- High-resolution X-ray Photoelectron Spectroscopy (XPS)
- Energy-dispersive X-ray Spectroscopy (EDX)
- Light microscope with 3D visualization
- FT-infrared spectroscopy (FTIR)
- Atomic force microscope (AFM)
- Scanning electron microscope (SEM)
- Profilometer
- Optical microscope with 3D function
- Taber test, Calotest (CATc), Ultrasonic bath
- Contact angle measuring instruments

Laboratory for surface treatment

- Selective plasma-chemical surface activation
- Functional coatings by means of PECVD processes
- Metallic and oxide coatings by means of PVD processes
- Plasma-based improvement of the biocompatibility of surfaces
- Plasma fine cleaning

Microbiological S2 laboratory

- Activities with pathogens in accordance with § 49 IfSG and § 13 BioStoffV
- Phytopathogenic and human pathogenic micro-organisms in risk groups 1 and 2
- Sterile work benches, incubators, transmission microscopes with CCD camera
- Cooperation with accredited and certified testing laboratories in the field of hygiene

Cell biology lab

- Cell based assays using human and animal primary cells, tissues, and cell lines
- Flow cytometry and sorting
- Protein and RNA molecular biology tools
- Extensive microscopy platform
- Omics Facilities: Transcriptomics and Proteomics (gel free mass spectrometry)

Plasma decontamination laboratory

Development of plasma processes for disinfection and sterilization of medical products, as well as for food hygiene:

- Reprocessing of medical devices based on plasma treatment
- Gas plasma processes for the gentle preservation of foodstuff
- Special plasma sources to be build into endoscopes for reprocessing
- Plasma processes for antimicrobial coating

Electric and welding arc laboratory

- Test station for high-current arcs
- Test station with fixed torch mounting
- Vacuum chamber
- Spectrographs and high-speed camera technology and streak camera
- Electrical measurement technology, optical sensors, thermography and pyrometry
- X-ray computer tomography

Laboratory for high-frequency engineering

Provision, optimization and development of methods and systems of high-frequency engineering:

- Frequency-resolved reflectometry in power controlled and in free radiating systems
- Microwave plasmas with mini-MIP and Plexc
- Frequency-resolved microwave interferometry

The Leibniz transfer portal can be used to retrieve other service offers, equipment, methods, qualification offers and technologies, as well as patents.
www.leibniz-transfer.de

Facts and figures

Budget:
The entire budget in 2015 amounted to € 16.4 million. Personnel expenditures amounted to approx. € 9 million (2015) and the cost for supplies was approx 2,9 € million (2015). In 2015 a total of € more than 4.5 million was invested in capital equipment of INP.

Staff:
The INP had 188 employees as of May 2015. This is including **84 scientific and technical positions**. The number of female employees is equivalent to 35,6 percent.

INP Main building

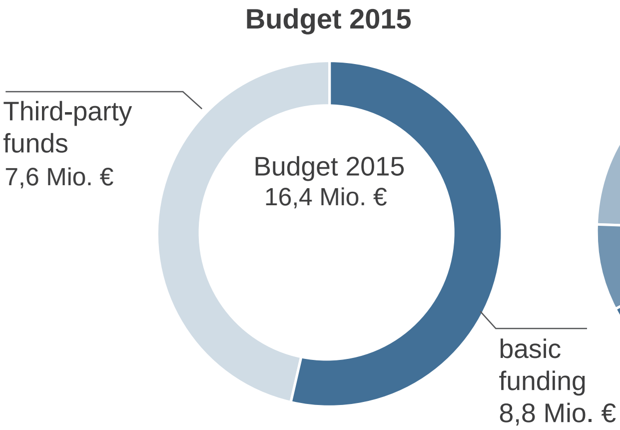
Main floor space 3.700 sqm

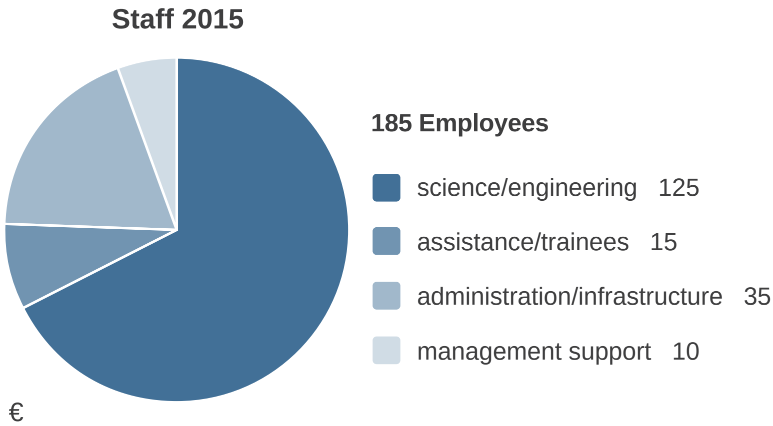
133 office work stations
41 laboratories

ZIK plasmatis extension building

floor space 540 sqm

30 office work stations
8 laboratories





Leibniz Research Alliances And Networks

Participation in Research Alliances of the Leibniz Association

The INP Greifswald participates in three collaborative research alliances formed by Leibniz institutions. The alliances are designed for a period of five to 15 years and are open for collaboration with universities, other non-university research institutions and infrastructure facilities as well as research groups abroad. These alliances use inter- and transdisciplinary approaches to address current scientific and socially relevant issues.

Leibniz Research Alliance "Energy Transition"

The German energy system is undergoing the most radical change in its history. The nuclear power phase-out and ambitious climate protection targets call for a far greater share of renewable energy sources, a drastic increase of energy efficiency, and substantial energy savings. These goals will not be reached through technical innovations alone. New forms of governance, improved regulations, original business models, and social innovations are equally crucial for success. Moreover, broad public consent is needed for an environmentally and socially sustainable transition. The Leibniz Research Alliance “Energy Transition” addresses these challenges with an interdisciplinary research approach that combines expertise from the humanities, the natural and the engineering sciences.
www.leibniz-energiewende.de

Leibniz Research Alliance "Sustainable Food Production and Healthy Nutrition"

Securing food supply is one of the greatest global challenges of the 21st century. In order to organise the sustainable production of foodstuffs, it must be considered along the entire value chain. The second challenge is to provide society with a healthy diet. This requires a causal analysis not only of the impact of foodstuffs on health but above all of dietary patterns. The research alliance sees itself as a transdisciplinary research structure. Most of the member institutions conduct research primarily in the fields of “sustainable food production” and “healthy nutrition”. An essential objective of the research alliance is to establish principles based on systems science to respond to the interdisciplinary challenge of “sustainable food production and healthy nutrition” in all its complexity and on all levels of the system, and to be able to provide society with scientifically sound and systematically tested recommendations for action.
www.leibniz-lebensmittel-und-ernaehrung.de

Leibniz Research Alliance "Medical Technology: Diagnosis, Monitoring and Therapy"

Valuable and affordable medical care is an important challenge for society, especially in view of an ageing population. Medical care is the main focus of this Leibniz Research Alliance. The alliance carefully develops innovative procedures that aid early disease detection, better control the effects of therapy and can easily be adapted to individual patients. These procedures improve treatment methods while minimizing their negative impact on patients. Telemedical and improved imaging examination methods, as well as the development of rapid testing designed for mobile use, also play an important role. Medical professionals, scientists and engineers work together intensively to ensure that the technical solutions adequately address the medical problems. Social scientists investigate questions of marketability and how society will respond to newly developed products.
www.leibniz-gemeinschaft.de

Participation in Networks of the Leibniz Association

Leibniz Networks have a particular thematic focus. They see themselves as a central contact point for their research field not only within the Leibniz Association but also for external project managers, policy-makers, the media and associations. They are located at the intersection between other networks, collating and mediating information, assisting in the search for project partners and channeling enquiries.

Application-Oriented Networking: the Leibniz Transfer Alliance Microelectronics

Within just a few decades, progress in semi-conductor technology has brought about ground-breaking new developments, especially in information and communication technologies. Microelectronics are part of every computer and of every mobile phone to the point that we cannot imagine our daily lives today without this miniaturised electronic circuitry. The Leibniz Transfer Alliance Microelectronics connects current know-how, research and development efforts and existing infrastructures at various Leibniz institutions in the fields of Micro- and Optoelectronics. Its goal is to accelerate and facilitate initiatives for exploitation-oriented cooperation.
www.leibniz-gemeinschaft.de

The Leibniz Nano-Network

The Leibniz Nano-Network unites Leibniz institutions that are skilled in the field of Nano-Technology.
The network's tasks include:

- Central contact point for Nano-Technology within the Leibniz Association and for external enquiries (e.g. from project management agencies, policy-makers, media, associations)
- Intersection with other Nano-Technology networks
- Compilation and exchange of information
- Effective search for project partners and connecting enquiries
- Joint/coordinated activities and events

The network is deliberately designed to remain adaptable to new developments.
www.leibniz-gemeinschaft.de

Leibniz Working Groups

Participation in Working Groups of the Leibniz Association

The INP Greifswald actively participates within the Leibniz Association in several working groups to support the Executive Boards for in-depth consideration of long-therm tasks of the entire scientific community. The President can establish and dissolve working groups, which are free to organise themselves as they choose.

Legal Issues and Personnel Working Group (AK Legal Issues)

This working group was established in order to promote the exchange of experience with legal issues among the institutes of the Leibniz Association. Since not every institute has a legal department the Legal Issues Group is a platform for exchange of information and experiences of all institutes. The group meets twice a year and is usually connected with the meetings of the Administrative Committee.

International Affairs Working Group (AK International Affairs)

The working group on international affairs meets regularly to exchange notes and thoughts on topics relevant for the international activities of the member institutes, including funding sources and forms of cooperation that have proven successful in the past. Furthermore, the group meetings serve as a forum to initiate, discuss, and develop international joint activities. In that manner, the meetings are to serve the international competitiveness of Leibniz Institutes.

Finance Working Group (AK Finance)

This group is open to the administrative heads of Leibniz institutions and pursues the following objectives: share best practice and formulate content-based positions on finance-related issues; support the Executive Board, Administrative Committee and Headquarters in making finance-related decisions; collaborate in continuing education activities on finance-related themes

Press and Public Outreach Working Group (AK Press)

The purpose of AK Press is to share experiences on issues relating to press and public outreach work as well as to draft strategies and measures for the Leibniz Association's internal and external communications.

The Europe Working Group (AK Europe)

This group is composed of EU advisors, third funding accountants as well as of scientists and research coordinators. It offers a platform for best practice exchange as regards any aspects of EU proposal preparation and project management. The working group gives input to position papers on administrative aspects and the rules for participation of the EU research funding programmes. The group is instrumental in ensuring the information flow between the EU Office and the Leibniz institutions.

The Sustainability Working Group (AK Sustainability)

This group is currently composed of two working groups: AK Sustainability Impact Assessment (SIA) is a permanent working group that addresses the politically, socially and scientifically relevant fields of impact assessment and sustainability evaluation using the example of strategies and tools. This is the basis on which political decision-makers are provided with scientifically sound information that flows into the policy-making process. Sustainability assessments are thus located at the intersection between politics, society and research. More than 25 Leibniz institutions from all five Sections have already conducted comprehensive research projects in this field and are the core of working group. One of SIA's targets is to bundle expertise and promote networking on impact assessment and sustainability evaluation within the Leibniz Association.

Knowledge Transfer Working Group (AK Knowledge Transfer)

Inter- and transdisciplinary knowledge transfer is a hallmark of the Leibniz Association. The science-based knowledge gathered in 89 institutes and facilities is translated and processed for societal stakeholders, leading to a fruitful exchange between science and society. The transfer activities in the Leibniz Association are as diverse as the topics and missions of its member institutions. They range from technology transfer and the provision of information infrastructure to policy consulting and information for the broad public. In this group, practitioners from the working level of all member institutions meet to discuss best practice transfer examples and successful strategies.

Equal Opportunities Working Group (AKC)

Opportunities Officers at Leibniz institutes regularly share their experiences in AKC. The Speakers' Council consists of ten representatives of all five Sections who deliberate statements and strategies in the area of equal opportunities, maintain contact with the Equal Opportunities Officers in the Sections and disseminate relevant information. The Speaker prepares statements, draws up papers for the working sessions and acts as a link between the Executive Board, Headquarters and AKC. Equal Opportunities Officers at Leibniz institutions act in accordance with individual agreements with the funders in the Land that hosts the institute, thereby implementing the "Implementation Agreement on the Framework Agreement on the Promotion of Research concerning Equal Opportunities for Women and Men with respect to Joint Research Funding – AVGlei" within the Leibniz Association.

Cooperation and networks

As a center of comprehensive competence for technological applications of plasmas, INP maintains various co-operations on national and international level with different university institutes, non-university research institutes, and companies.

Networking with universities in Germany and abroad

The Institute has maintained long-standing cooperation agreements with universities and technical universities in the region, in Germany and abroad.

Notable are in particular the close cooperation with the Institute of Physics at the **Ernst Moritz Arndt University of Greifswald** and the **University Medicine Greifswald**. INP offers lectures, as well as support for dissertations, undergraduate, master and bachelor theses. Interdisciplinary cooperation with other departments at the Ernst Moritz Arndt University of Greifswald such as medicine, pharmacy or mathematics has made it possible to establish successful joint initiatives such as the Plasmatis Centre for Innovation Competence (ZIK plasmatis) or the world's first professorship of plasma medicine in cooperation between University Medicine Greifswald and INP Greifswald since 2011.

Together with the Institute of Physics at the Ernst Moritz Arndt University of Greifswald, Germany, and the Max Planck Institute of Plasma Physics, Greifswald Branch, INP had conducted a graduate school that offered structured training for doctoral students since 2001. Since 2012, this graduate school is a part of the **"International Helmholtz Graduate School for Plasma Physics"**, and is jointly run by the Max Planck Institute for Plasma Physics, the Technical University of Munich and the Ernst Moritz Arndt University of Greifswald in cooperation with the Leibniz Computer Centre in Garching and INP Greifswald as associated partners.

The intensive cooperation with the **University of Rostock** has led to two joint appointments in 2011: a professorship for High-voltage and High-current Engineering at the Faculty of Computer Science and Electrical Engineering, as well as a professorship for Bioelectrics in the field of applied physics in the Faculty of Mathematics and Natural Sciences at the University of Rostock. Furthermore, there are long-term interdisciplinary research partnerships with scientific departments in biomedicine and the Centre for Life Science Automation (CELISCA). This cooperation is also reflected in the German Federal Ministry of Education and Research's Innovative Regional Growth Core called Centifluidic Technologies (2012 - 2014), in which INP cooperates with scientific departments at the Universities of Greifswald and Rostock. At **Stralsund University of Applied Sciences** the plasma technology module was established in the master's degree program for electrical engineering in 2005, with an honorary professorship created and filled by a distinguished senior scientist affiliated with the INP.

Relations with the following German institutions in the areas of plasma physics, plasma technology and plasma medicine are noteworthy too:

- Charité - Universitätsmedizin Berlin (medical faculty, which serves Humboldt Universtität zu Berlin and Freie Universität Berlin)
- Christian Albrechts Universität Kiel (CAU)
- Medizinische Universität Innsbruck (Medical University of Innsbruck)
- Ruhr-Universität Bochum (RUB)
- Rheinisch-Westfälische Technische Hochschule Aachen (RWTH University, Aachen)
- Technische Universität Dortmund (TU Dortmund)
- Technische Universität Dresden (TU Dresden)
- Technische Universität Berlin (TU Berlin)
- Universität Stuttgart (University of Stuttgart)

Internationally, INP holds strong cooperative partnerships:

- Cambridge University, Cambridge, United Kingdom
- Czech Technical University in Prague (CTU), Prague, Czech Republic
- École polytechnique - Université Paris-Saclay, France
- Eindhoven Technical University, Netherlands
- Hokkaido University, Hokkaido, Japan
- Masaryk University, Brno, Czech Republic
- Old Dominion University Norfolk (ODU), Virginia, USA
- St. Petersburg State University (SPSU), St. Petersburg, Russia
- Université Toulouse III - Paul Sabatier, Toulouse, France

The international relations include guest professorships at Old Dominion University, New York University and St. Petersburg State University and an honorary professorship at St. Petersburg State Polytechnical University. There are also agreements that relate to the joint training of doctoral students and other qualifying degrees. The close cooperation with the universities of Prague and Brno in the Czech Republic also includes a joint training agreement, guest lectures and internships for junior scientists.

INP is further paying attention to nations catching up in plasma technology. These include China, South Korea and Taiwan, which have developed or significantly expanded into these fields with the support of substantial government-funded program. Cooperation partnerships in these countries are currently being initiated. A cooperation agreement has been signed with Tsinghua University in Beijing and Peking University. Joint research projects have already been carried out with partners at National Cheng Kung University Tainan, Taiwan.

Professors at INP

- *Prof. Dr. Klaus-Dieter Weltmann*
  University of Greifswald - Experimental Physics
  New York University (Visiting Professor)

- *Prof. Dr. Thomas von Woedtke*
  University of Greifswald - Plasma Medicine

- *Prof. Dr. Jürgen Kolb*
  University of Rostock – Bioelectrics
  Old Dominion University (Adjunct Associate Professor)

- *Prof. Dr. Jürgen Röpcke*
  Stralsund University of Applied Sciences - Plasma Technology (Honorary Professor)

- *Prof. (St. Petersburg) Dr. Dirk Uhrlandt*
  Saint-Petersburg State University (Honorary Professor)
  Saint-Petersburg State Polytechnical University (Visiting Professor)

Networking in strategic and economic initiatives

Networking in strategic and economic initiatives BalticNet-PlasmaTec (BNPT)

The technology cluster BalticNet-PlasmaTec supports partners in establishing innovative commercial plasma technologies for the economy. As one of the most important plasma technology clusters in Northern Europe, BNPT's aim is to raise the perception of the plasma technology in society. BNPT is a contact partner for interested parties in the Baltic Sea region who intend to expand their own technical and economic potential in using the plasma technology. The network has currently 71 members from 15 different countries. *www.balticnet-plasmatec.org*

Network of Competence Industrial Plasma Surface Technology (INPLAS)

INPLAS is an alliance of industry and research for the purpose of promoting the use and development of industrial plasma surface technology, in particular by increasing the competitiveness and reputation of members on the national and international level. Since 2005, INP has been a member in the INPLAS network with the director of the INP also serving on the Board of Directors of the alliance. *www.inplas.de*

European Society of Thin Films (EFDS)

The European Society of Thin Films (EFDS) is a non-profit scientific research society in the plasma-enhanced deposition and vacuum coating industry. The European Society of Thin Films promotes close collaboration between industrial enterprises and research institutions and supports research activities and the application of plasma surface engineering and thin-film technologies in practice. Members of EFDS, namely companies, research institutions and individuals, are active in the fields of process development, plant engineering, materials science, commercial coating, or other surface engineering applications. *www.efds.org*

Deutsche Physikalische Gesellschaft e. V. (DPG)

The DPG serves exclusively and directly the fields of pure and applied physics, bring its members and all physicists living in Germany closer together, represent their entirety outwards as well as foster the exchange of ideas between its members and foreign colleagues. The association for plasma physics brings together researcher in the field of plasma science and their applications. *www.dpg-physik.de*

Deutsche Gesellschaft für Plasmatechnologie (DGPT)

The association has the aim to enhance the visibility of plasma technology in general and to bring together experts in all relevant fields of plasma technology. It also organizes conferences, supports training activities of students and serves as consultant to industry and politics. *www.plasmatechnologie.org*

Nationales Zentrum für Plasmamedizin e. V. (NZPM)

This national network of all research groups in the field of plasma medicine was founded in June 2013 at the initiative and with the cooperation of INP. The virtual center brings together companies, research institutes and universities in the fields of medicine, biology, pharmacy, physics and engineering. The association has the purpose to promote research and development of plasma medicine throughout Germany. *www.plasma-medizin.de*

Regionale Wirtschaftsinitiative Ost Mecklenburg-Vorpommern e. V.
This association is a centerpiece of the regional management office in the state of Mecklenburg-Western Pomerania. Its goal is the improvement of the regional economic structures. INP is among the more than 90 members and thereby in close cooperation with the regional economy. *www.rwi-online.de*

International Bioelectrics Consortium
INP joined the competence network "International Bioelectrics Consortium" as one of the first partner in 2007. The network achieves an exchange of information and research personnel with and between the 12 currently participating partners from Germany, France, Italy, Czech Republic, Slovenia, Japan and the United States. *https://www.odu.edu/bioelectrics/ibc*

The director of the institute is, inter alia, a member of the advisory board for photonics/optical technologies at the German Federal Ministry of Education and Research (BMBF). Furthermore, INP takes active part in the VDI (German Association of Engineers) standardization committee for air pollution.

ASSOCIATIONS

INP is continuously active in a variety of national research projects that are funded by the federal government. During the reporting period, INP was responsible for the coordination of the Plasmatis Centre for Innovation Competence (ZIK plasmatis) with two junior scientist groups "Cellular Effects" and "Extracellular Effects".

INP has intensified its activities in the acquisition of international projects. It was involved in several EU projects during the reporting period. In 2013 the project "PlasmaShape" funded by the European Union (2,46 Mio EUR) was launched at INP. The project's aim is to expand networking efforts of the INP in Europe through staff exchanges, investments in equipment, hiring of highly qualified scientists and targeted marketing activities (see also page 16).

In addition to the cooperation with universities, technical universities and universities of applied sciences, INP maintains close relations with non-university research institutes in Germany and abroad. The collaboration includes institutions in the Leibniz Association such as:

- Leibniz Institute for Catalysis at the University of Rostock (LIKAT Rostock)
- Leibniz Institute for Crystal Growth Berlin (IKZ)
- Leibniz Institute for Agricultural Engineering Potsdam-Bornim (ATB)
- Leibniz Institute of Freshwater Ecology and Inland Fisheries Berlin (IGB)
- Ferdinand-Braun-Institut, Leibniz-Institut fuer Hoechstfrequenztechnik Berlin (FBH)
- Institutes in the Fraunhofer Gesellschaft (Fraunhofer Society) such as:
- Fraunhofer Institute for Surface Engineering and Thin Films Braunschweig (IST)
- Fraunhofer Institute for Manufacturing Technology and Advanced Materials Dresden (IFAM)
- Fraunhofer Institute for Applied Optics and Precision Engineering Jena (IOF)
- Fraunhofer Institute for Material and Beam Technology Dresden (IWS)
- and the Helmholtz Centers for
- Helmholtz Centre Geesthacht (HZG), Centre for Materials and Costal Research
- Helmholtz-Zentrum Berlin für Materialien und Energie (HZB)

as well as the Max Planck Institute for Plasma Physics, Greifswald branch, which is an associated member of the Helmholtz Association.

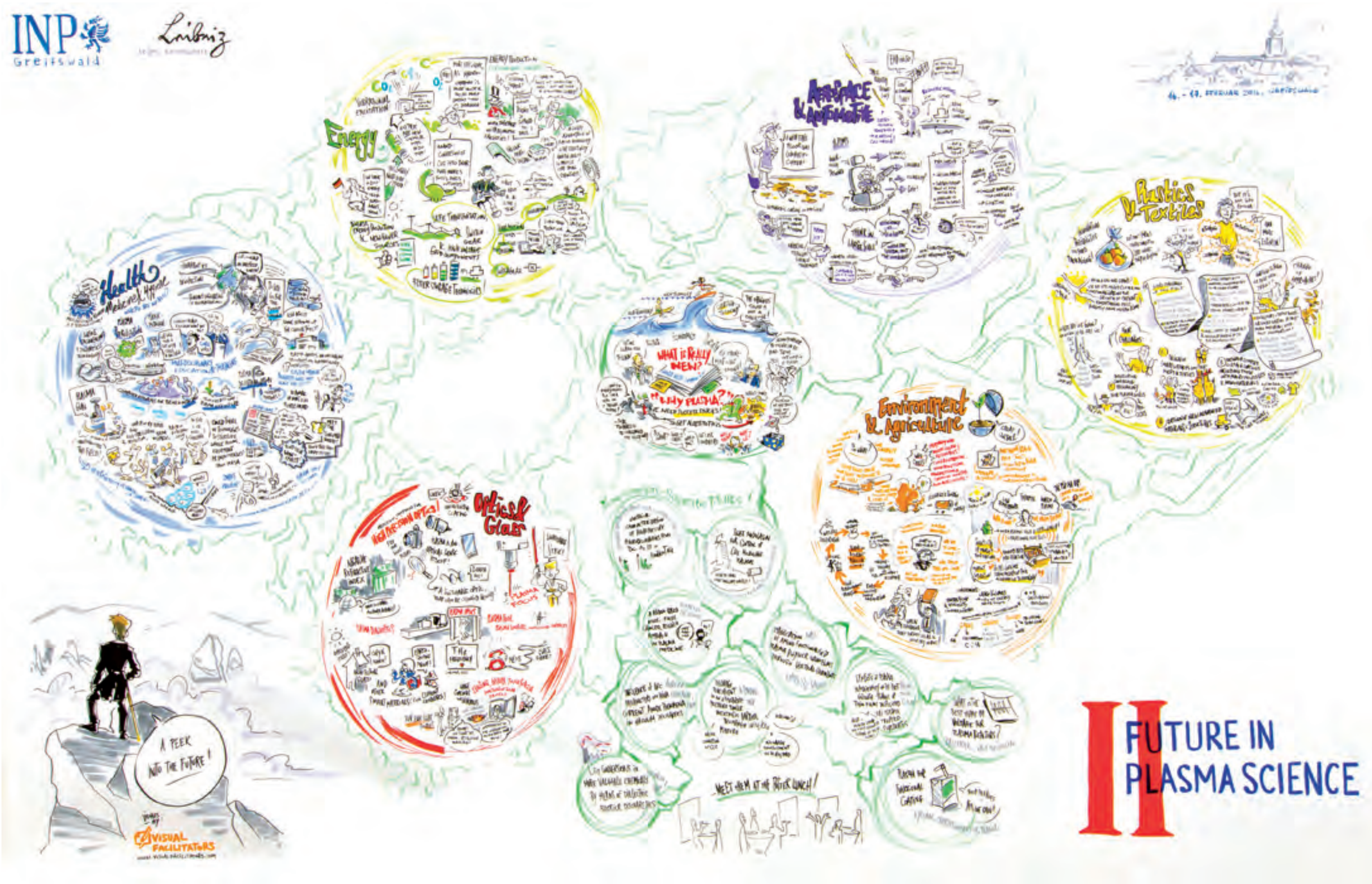
Network of Leibniz application laboratories: the interface between business and science
The rapid implementation of research results in products, processes and services is crucial to the competitiveness of companies on the market. The applications laboratories implement research results in practice-oriented, functional models and demonstrators, thereby creating active interfaces between business and science. The laboratories work together nationally and thus offer a broad research portfolio for technology developments. They are funded by the German Federal Ministry of Transport, Building and Urban Affairs in the framework of the innovation competition "Economy Meets Science".

The application laboratory for surface technology is located at the Leibniz Institute for Plasma Science and Technology in Greifswald (INP). Industry services are offered to find solutions for customer-specific problems. A wide range of low pressure and atmospheric pressure plasma processes is available. The application laboratory has already produced industry-standard products (including kINPen for plasma treatments under atmospheric pressure, SurfActive One as an entry-level model for vacuum processes), which are sold through our spin-offs neoplas GmbH (www.neoplas.eu) and neoplas tools GmbH (www.neoplas-tools.eu).

Workshops Future in Plasma Science (FIPS 1 & 2)

For the first time the INP hosted two events to develop new strategic areas in plasma science: "Future in Plasma Science". During both workshops the role of plasma research and development for future and emerging technologies were discussed. For this we brought together more than 100 scientists from 19 countries - established scientists and young researchers with expertise in different fields of plasma science to open up promising avenues in plasma technology. We identified six topics like 'Environment & Hygiene' or 'Aerospace & Automotive' to structure the events in order to cover all essential fields of plasma science and to prepare grounds for the discussion on future developments in those topics based on the researcher's scientific background.

The aim for the first workshop from July 12 to 15, 2015, was to start a joint consensus paper for national and international stakeholders to emphasise the importance of plasma technology facing the future challenges in the next decades. During and subsequent to the event we started to arrange a follow-up meeting to work on theme specific white papers for the scientific community and strong emphasis on cooperation interests not only between the INP and its partners but also among the partnering institutions. So from February 15 to 18, 2016 the second workshop "Future in Plasma Science II" took place at the INP. The workshops on Future in Plasma Science were organised and funded within the EU-funded project PlasmaShape.



HAKONE XIV

The 14th International Symposium on High Pressure Low Temperature Plasma Chemistry (HAKONE XIV) was held from September 21 to 26, 2014 in Zinnowitz, Germany. HAKONE XIV was jointly organized by the Institute of Physics of the University of Greifswald (IfP) and the INP Greifswald. With this symposium a series of successful conferences devoted to the fundamentals and applications of non-thermal plasmas at elevated pressures was continued. 154 regular attendees and 15 accompanying persons and guests from 21 different countries participated at the symposium. HAKONE XIV provided a forum for sharing knowledge, experience and creative ideas in an informal atmosphere. In particular the next generation of researchers can meet with leading scientists in their field in a familiar atmosphere. 37 participants were students or PhD-students.

Speakers' Council of the Equal Opportunities Working Group (AKC)

The Speakers' Council as the consists of ten Gender equality officers as representatives of all five sections of Leibniz Association who deliberate statements and strategies in the area of equal opportunities, maintain contact with the equal opportunities officers in the sections and disseminate relevant information. Since June 2015 the Gender equality officer of the INP is one of these representatives for section D (mathematics, natural sciences and engineering).

Total E-Quality Certificate awarded in 2014

The Leibniz Institute of Plasma Science and Technology has been awarded the TOTAL E-QUALITY certificate for 2014 to 2016 for its vital institute culture of equal opportunities. The certificate is awarded by the TOTAL E-QUALITY Deutschland e. V. The certificate has been developed by means of the Federal Ministry of Education and Research and the European Union and is awarded for acting in an exemplary manner for a personnel policy oriented towards equal opportunities. In 2017 the INP will apply with an update for that certificate to be prolonged until 2019.

ESCAMPIG XXII

The 22th Europhysics Conference on Atomic & Molecular Physics of Ionized Gases (ESCAMPIG XXII) was held from July 15 to 19, 2014 in Greifswald, Germany. The ESCAMPIG is an international biennial conference of the European Physical Society (EPS). The conference topics comprise basic and applied plasma research ranging from atomic and molecular processes in plasmas and plasma surface interaction to self-organization in plasmas and to the new research fields with low and high pressure plasma sources. The XXII ESCAMPIG was organized jointly by the Institute of Physics of the University of Greifswald (IfP), the INP Greifswald and the Max Planck Institute for Plasma Physics (IPP), Greifswald. 222 attendees from 21 different countries participated at the conference.

Opening of the Arc Laboratory

The grand opening of the tailored and therefore unique arc laboratory opened an excellent basis for detailed arc research for basic and applied research to attract industrial customer. At the opening ceremony of the arc laboratory on June 03 and 04, 2015 guests from industry, politics and science were invited. The electric arc laboratory serves primarily for application-oriented research for the increase of reliability and lifetime of switching devices. Therefore, experiments on arcs in vacuum or at atmospheric pressure are utilized to study the arc behaviour and the electrode load in low, middle and high voltage switchgears at different current pulse shapes. Mr. Venohr, Ministry of Education, Science and Culture Mecklenburg Vorpommern and Prof. Berger, Technische Universität Ilmenau, accentuated in their opening remarks the importance of application-oriented research in the newly installed arc laboratory in regard to the current requirements of the energy transition.

User Convention Surface Technologies 2014

The area of surface modification by plasma technologies is an important research field at INP. To foster the cooperation with regional and national companies we organized a special user convention addressing solely companies. The focus of the event was to display actively the technological potential of plasma in the areas of high-tech materials in life science and engineering. More than 50 visitors from 30 different companies visited the INP to receive impressions about the capacities INP offers in the area of surface modification. The program was split into five sessions: Plasma spraying, plasma polishing, atmospheric plasma sources and coatings, HiPIMS (High-power-impulse Magnetron Sputtering), and low pressure plasma application. Each of the sessions started with a presentation of representatives from companies using already plasma surface modification technologies. Additionally laboratory tours and the possibility to have bilateral meetings were offered to the company representatives. As a result, the INP received several offers for bilateral projects, for the participation in common project proposals and for a contribution in a project committee. It is planned to repeat this successful event in 2016.

Exhibition

Participation of INP at Phänomenta

Since 2015, the INP exhibit at the Science Center Phänomenta in Peenemünde with various exhibits and an easily understandable film on plasma medicine. The aim is to draw attention to the multifaceted topic and to increase public interest in plasma physics. This project has received funding from the Federal Ministry of Education and Research (BMBF).

Awards 2015

Best Presenter Award 2015
Ms. Nora Stolz
International Conference of Food Security and Nutrition (ICFSN 2015) in Florenz, Italy

Best Student Paper Award 2015
Ms. Anna Steuer
1st World Congress on Electroporation in Portoroz, Slovenia

Best Student Paper Award 2015
Mr. Robert Banaschik
42nd IEEE International Conference on Plasma Science (ICOPS) in Antalya, Turkey

1st Prize Invention StartUp Prize 2015,
2nd Place Inno Award 2015,
Winner Greifswald University Club 2015
INP EXIST Project Coldplasmatech

INP Research Award
At INP annually two scientists were awarded for outstanding scientific publications with the "INP Research Award":

- **INP Junior Resarch Award 2015**
  Dr. Torsten Gerling
  Gerling, T.; Bussiahn, R.; Wilke, C.; Weltmann, K.-D.: "Time resolved ion density determination by electrical current measurements in an atmospheric-pressure argon plasma", Europhys. Lett. 105 (2014) 25001
- **INP Senior Research Award 2015**
  Dr. Angela Kruth
  Kruth, A.; Peglow, S.; Quade, A.; Pohl, M.-M.; Foest, R.; Brüser, V.; Weltmann, K.-D.: "Structural and Photoelectrochemical Properties of DC Magnetron-Sputtered TiO2 Layers on FTO", J. Phys. Chem. C 118 (2014) 25234-25244

Awards 2014

Plasma Medicine Award 2014
Prof. Dr. Klaus-Dieter Weltmann
International Society of Plasma Medicine (ISPM),
5th International Conference for Plasma Medicine (ICPM5) in Nara, Japan

Noah Hershkowitz Ealry Career Award 2014
Dr. Ronny Brandenburg
Journal: Plasma Sources Science and Technology

Ludwig-Bölkow-Technologiepreis 2014
For medical plasma device kINPen® MED, a joint development of neoplas tools GmbH, INP Greifswald, in collaboration with University of Greifswald and Charité – Universitätsmedizin Berlin.
INP Start-up: neoplas tools GmbH
Federal State of Mecklenburg-Vorpommern and the Chamber of Industry and Commerce

1st Prize UniQUE Award 2014,
2nd Place Bio-Security Competition 2014,
Best Technology Award – BioMedizin Dortmund 2014,
1st Prize (Concept) Science4Life Venture Cup 2014,
1st Prize Start2Grow Business Competition 2014,
1st Prize Business Concept Competition Startbahn Ruhr,
2nd Place (Concept) BPW 2014
EXIST Project Coldplasmatech

INP Research Award
At INP annually two scientists were awarded for outstanding scientific publications with the "INP Research Award":

- **INP Junior Research Award 2014**
  Dr. Markus Becker
  Becker, M.M.; Hoder, T.; Brandenburg, R.; Loffhagen, D.: "Analysis of microdischarges in asymmetric delectric barrier discharges in argon", J. Phys. D: Appl. Phys. 46 (2013) 355203
- **INP Senior Research Award 2014**
  Prof. Thomas von Woedtke
  von Woedtke, Th.; Reuter, S.; Masur, K.; Weltmann, K.-D.: "Plasmas for Medicine", Phys. Reports 530 (2013) 291

Center for Innovation Competence “plasmatis – plasma plus cell”

In December 2009 the Center for Innovation Competence ZIK plasmatis was started. This BMBF funded project was designed for outstanding basic research bringing together the expertise of biochemists, biologists, pharmacists and plasma physicists. With combined forces this team was set up to investigate the influence of cold physical plasmas on wound healing processes. Over the past five years the ZIK plasmatis team reached a leading position within the field of basic research on Plasma Medicine, and the results count to the most cited in this young field of interdisciplinary research. It can be stated with certainty that the hypothesis on which the center of plasmatis was based on: “Plasmas can heal” now stands on a solid scientific base.

The focus of the research group “Cellular Effects” was to investigate molecular mechanisms of the influence of cold plasmas on eukaryotic cells. The aim was to identify the responsible molecules in order to activate cellular processes such as cell proliferation, cell signaling, gene activation as well as post translational protein modification due to different plasma sources and plasma parameters. Especially the signal transduction – starting from plasma activated signaling cascades leading to gene activation and finally to the secretion of hormones and cytokines important for cell stimulation and regeneration is one central result of this team. Also very important was the discovery of the selectivity of cold plasmas by influencing the cellular redox-balance of target cells, which was only possible by a joint research with the “Extracellular Research” team of plasmatis.

The aim of the research group „Extracellular Effects“ was to tune the composition of the plasmas and the treated biologically relevant liquids, in order to tailor the reactive species composition of the liquid cell environment. The external control on the reactive species composition was gained by evaluating and applying the results from plasma diagnostic studies in combination with numerical modelling. Reactive species were to be controlled separately to identify the relevant processes of plasma wound healing together with the research group “Cellular Effects”.
Funding: Federal Ministry of Education and Research (BMBF)

PlasmaShape

PlasmaShape is funded in the framework of Research Programme 7 (REG-POT-Capacities) of the European Commission and allows INP to hire internationally experienced scientists for two to three years. In addition, the acquisition of special laboratory equipment provides the INP with unique instrumentation that is difficult to be found elsewhere in Germany. The equipment is also available to cooperation partners. Visits by cooperation partners, as well as delegations of INP scientists to cooperation partners, are also supported by PlasmaShape in order to expand existing partnerships and to initiate new strategic alliances. Intellectual property for low temperature plasmas that is generated at the INP is supervised by INP’s own patent manager. The project is funded with EUR 2.64 million for the three years (6/2013-05/2016) and, with the described strategies, should lead to a sustainable development of the Institute on European level. This is also of great benefit for the region and the business location of Greifswald.
This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 316216. *www.plasmashape.eu*
Funding: European Commission

Development and implementation of novel methods for the exploitation of scientific knowledge (WV²)

“Technology transfer” is an attempt to transfer the knowledge created in research institutions directly or indirectly into economic applications. For this purpose, a number of structures and methods have been created for non-university institutes, primarily relating to "technological" innovations. The INP already had experience in knowledge and technology transfer and has developed an exploitation structure in 2005. Nevertheless, it considers the use of codified scientific and technical knowledge, irrespective of specific technologies, as a transfer potential. Within this project methods and tools for an improved transfer of research results have been tested in commercial applications and implemented in parts. The project was able to provide a much greater attention of the society on "plasma". The INP has strategically realigned its knowledge and technology transfer. Through the project the Institute has been strongly supported in being prepared for a rapidly changing market research. Especially the compliance issue within the meaning of lawful and value-oriented action should be seen as professionalization step of INP especially to the industry, but also in relation to other research facilities as well as the Institute's. The skills acquired are transferable to other research institutions. In this way a professional dissemination of "new instruments" in potentially all German research institutions is conceivable.
Funding: Federal Ministry of Education and Research (BMBF, FKZ 01SF1151)
www.youtube.com.
Funding: Federal Ministry of Education and Research (BMBF)

Plasmamedicine MV

The project "Plasma medicine – a lighthouse of healthcare industry in Mecklenburg-Vorpommern" exemplifies plasma medicine as a core competency of the healthcare industry in Mecklenburg-Vorpommern and beyond. Plasma medicine is a relatively young research area of medicine. The aim of the project is to systematically inform future customers and users about the possibilities of plasma medicine with a wide, target-group-specific media campaign. In close cooperation with Klinikum Karlsburg numerous articles and reports have been placed in regional/national media (newspapers, magazines, TV) and various trade fairs, congresses and informational evenings have been attended. The resonance is impressive, despite the early stage of the project: From "simple" patients to industrial partners, from regional doctors to healthcare facilities outside Europe: the demands are steadily increasing.
Funding: Ministry of Education, Science and Culture in Mecklenburg-Vorpommern funded by the "European Regional Development Fund (ERDF)".

Plasma medical research - New pharmaceutical and medical fields of application

Synergies between research conducted within the BMBF-funded project Campus PlasmaMed and the "Plasmatis" Centre for Innovation Competence (ZIK) "plasmatis – plasma plus cell" have led to the successful introduction of plasma-based processes in medical research and practice. While the goals of Campus PlasmaMed were application oriented, are the objectives of Plasmatis dedicated to fundamental research. The Institute is striving to further pursue the directions of both projects. In particular ideas that could not be pursued on account different priorities defined in the framework of Campus PlasmaMed can now be revisited and studied with respect to applications. The expected outcome is a sustainable basis for research based procedures and the transfer of results into medicine and pharmaceutics that will secure the unique position of plasma medicine in Mecklenburg-Western Pomerania in coming years.

The scientifically accompanied and supportive testing of the therapeutic application of atmospheric pressure plasma sources will be expanded in dentistry and extended to include the new fields of maxillofacial surgery and pulmonology. The findings with respect to the role of liquids in the mediation of biological plasma effects are the basis for opening up the new field of plasma pharmacy. The project is being funded by the Ministry of Education, Science and Culture in the state of Mecklenburg-Vorpommern over the next year and a half with 1.5 million euros.
Funding: Ministry of Education, Science and Culture in Mecklenburg-Vorpommern funded by the "European Regional Development Fund (ERDF)".

Pulsed discharges in water for the degradation of pharmaceutical residues (PLASWAS)

The motivation of this project is the raising issue that pharmaceutical residues and problematic bacteria increasingly pollute water. Current techniques of water purification are inadequate to cope with these problems. With energy efficient ultrashort high voltage pulses physical plasma can be generated directly in water. The plasma decomposes at the same time organic chemical compounds and germs through multiple reaction pathways.

General Advantages

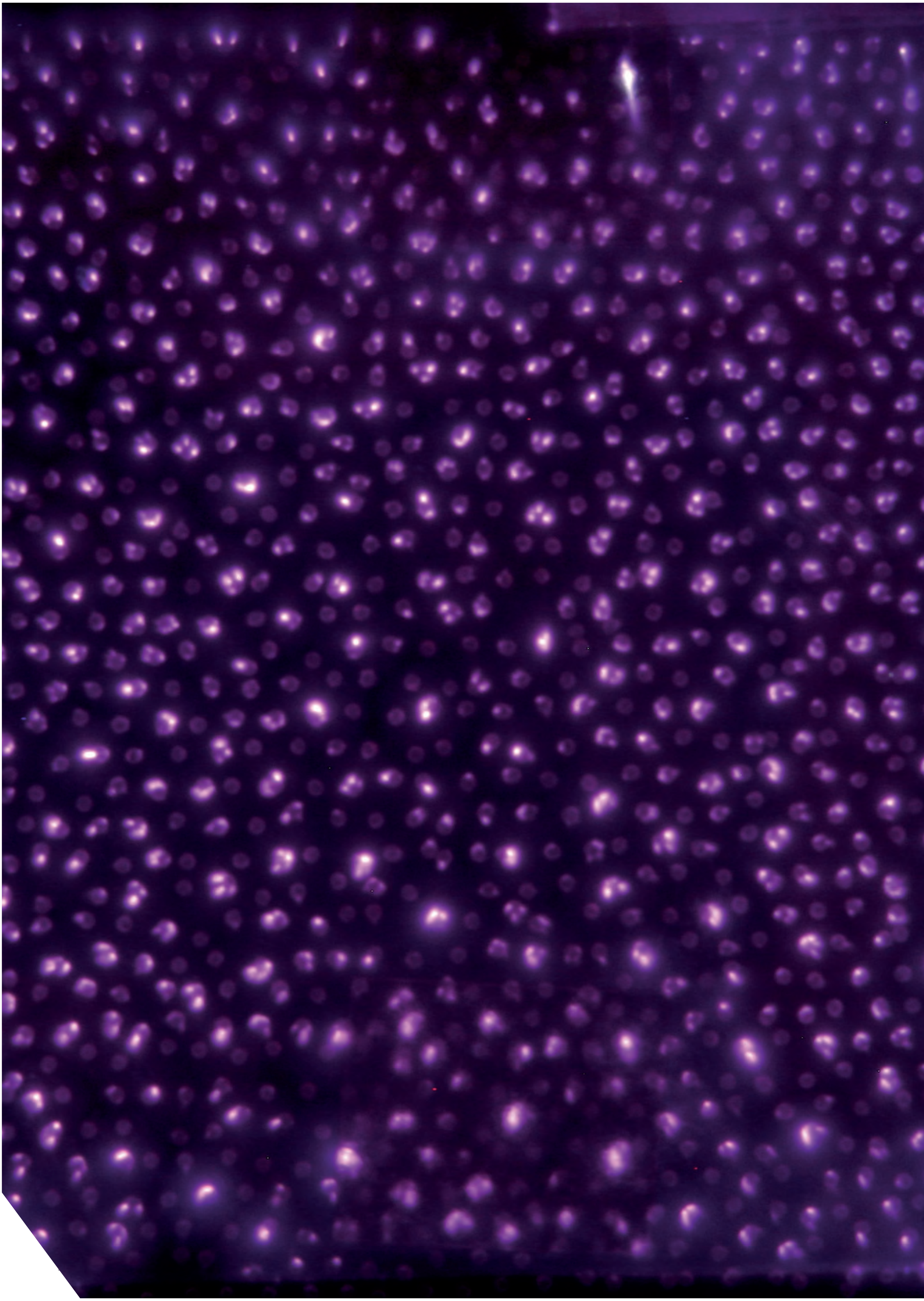
- No chemicals (i.e. chlorine) or catalysts are necessary;
- Higher effectiveness compared to chlorination and ozonation;
- Inactivation of microorganisms and decomposition of organic compounds;
- Plasma treatments can supplement and substitute UV-treatments;
- Plasma treatments offer high penetration depths, regardless of turbidity;

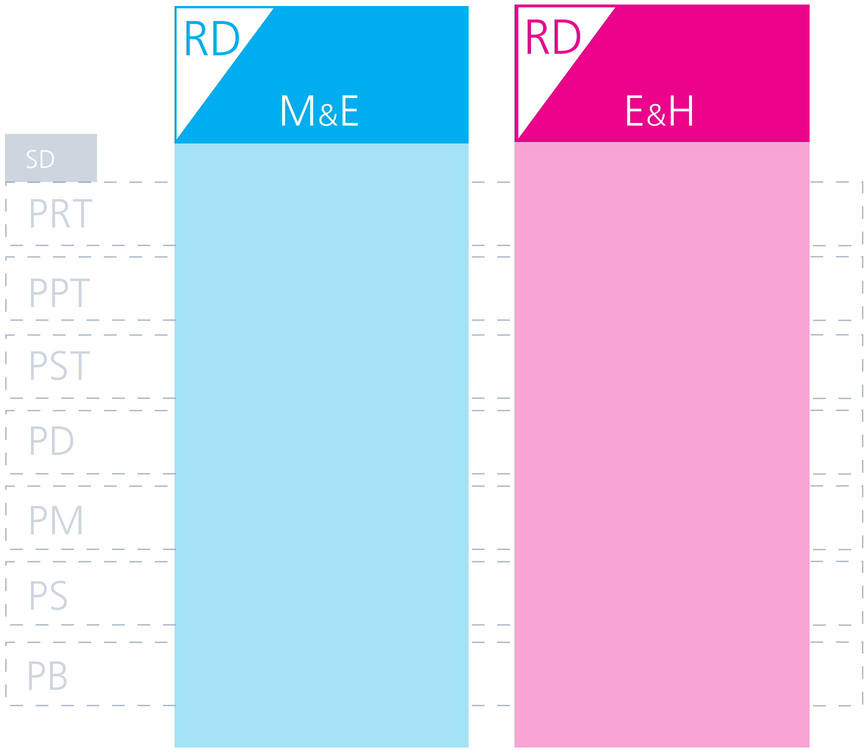
Pulsed discharges effectively decompose organic compounds, which cannot be dealt with using chlorine or ozone. Furthermore, high local electric fields provide efficient additional physical mechanisms for the killing of bacteria. PLASWAS as so-called scientific preliminary project makes an important contribution to the rapid transfer of new scientific findings into innovative products.
Funding: Federal Ministry of Education and Research (BMBF)

EXIST Research Transfer:

Medical devices for the plasma-physical therapy of large area skin diseases – Plasmatherapy

During the early years of plasma medical research specialists at INP invented a special large area and flexible plasma source which should be able to treat large area wounds. This invention inspired the INP to apply for a special project funding to prepare the conditions for the set-up of another spin-off company of the institute. Fortunately the INP get funded by the Federal Ministry for Economic Affairs and Energy under the EXIST programme. After acquiring the project team (Dr. C.C. Mahrenholz, T. Güra from external, and Dr. R. Bussiahn, S. Krafzcyk from INP) the project started in 2013. The scientific core of the project was to develop a special wound pad designed by different layers of silicone and a flexible plasma source. This so-called plasma-patch is controlled by an external power supply to avoid injuries of the patients when applying the pad to the wound. The official foundation of the new spin-off company, Coldplasmatech GmbH, took place in July 2015. It is expected that the company receives another funding for the transformation of the prototype into a certified medical product. And the INP has so again proved its motto: From Idea to Prototype.
Funding: Federal Ministry for Economic Affairs and Energy, reference 03EFAMV012





Matrix structure of the Research Divisions (RD) and Scientific Departments (SD)

Research Divisions Plasmas for Materials & Energy (RD M&E)

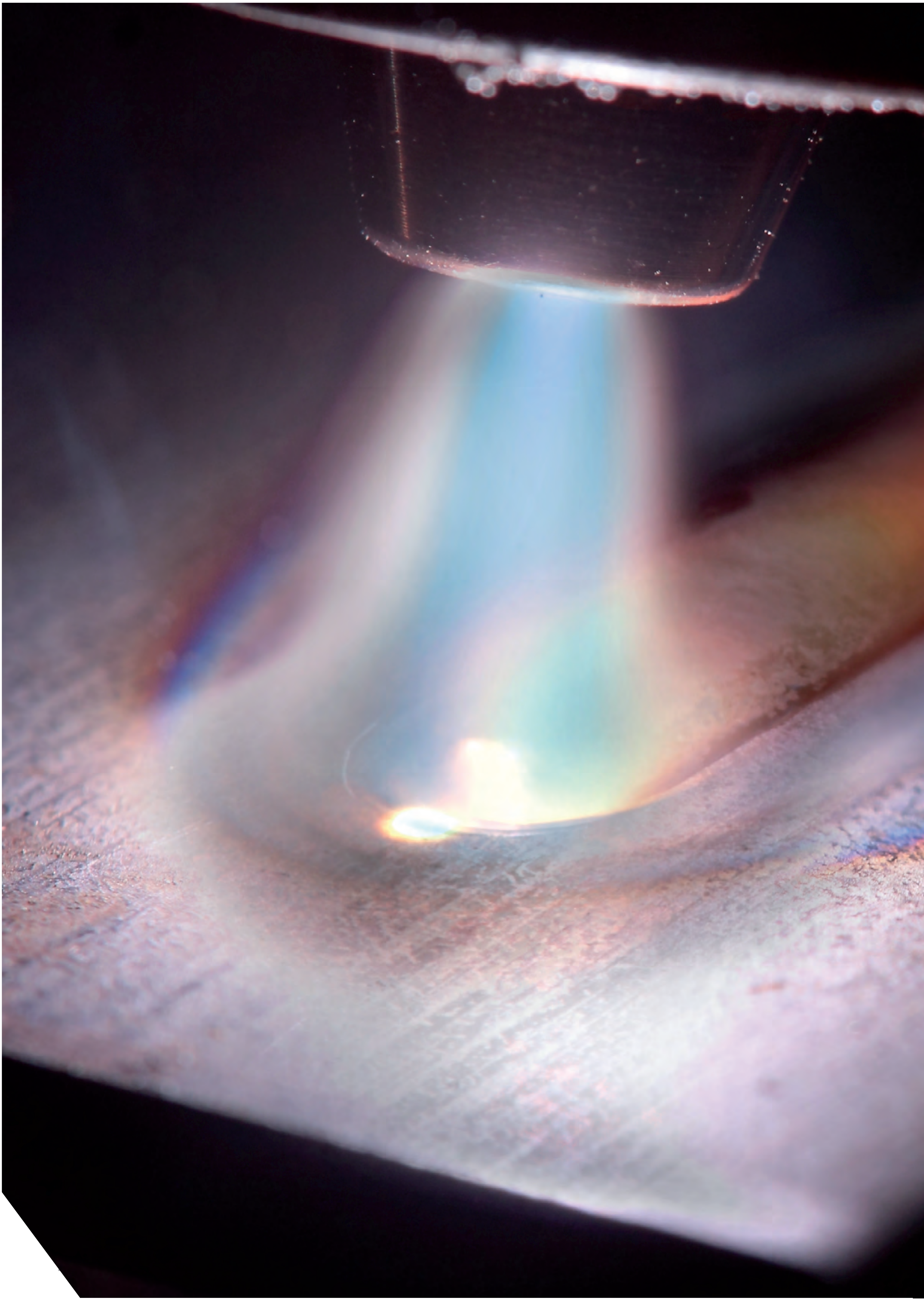
- Research Programme Surfaces and Materials
- Research Programme Process Monitoring
- Research Programme Welding and Switching

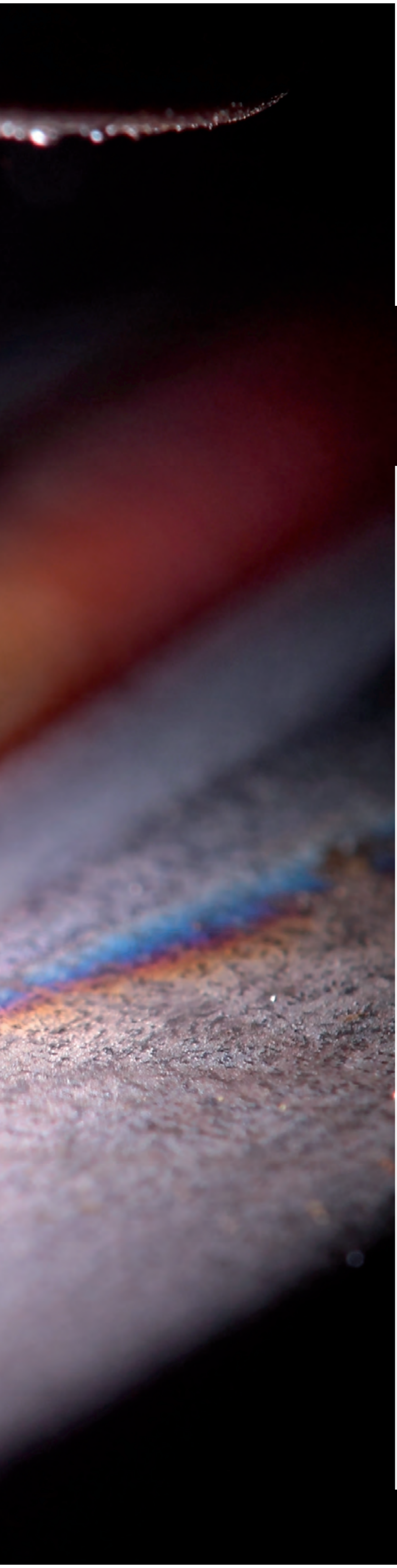
Research Divisions Plasmas for Environment & Health (RD E&H)

- Research Programme Bioactive Surfaces
- Research Programme Plasma Medicine
- Research Programme Decontamination

Scientific Departments (SD)

- Plasma Radiation Techniques (PRT)
- Plasma Process Technology (PPT)
- Plasma Surface Technology (PST)
- Plasma Diagnostics (PD)
- Plasma Modelling (PM)
- Plasma Sources (PS)
- Plasma Bioengineering (PB)
- Plasma Life Science (PL)





RESEARCH DIVISION

MATERIALS & ENERGY

Overview

This research division combines topics of the production of functional surfaces, thin films and catalytic materials by means of plasma processes with diagnostic methods for plasma process monitoring and issues of electrical power and process engineering particularly in the field of arcs. The combination of electrical engineering with plasma technology constitutes the origin of the gas discharge physics. As unique selling point, the strategy of the research division pursues the consequent coupling of scientifically sophisticated plasma modelling with spatially and temporally high-resolution diagnostic methods for application relevant issues in the topics mentioned above using state-of-the-art experimental laboratories. The focus of the basic research is on the specific surface treatment by means of non-thermal plasmas at atmospheric pressure as well as on the interaction of thermal plasmas with electrodes. Plasma technology allows uniquely the generation of application-specific surface and material properties, up to new materials in the photovoltaic and hydrogen technology. The control of arcs and other plasma phenomena is essential for the device functionality in the electrical power supply and the process reliability in applications of the process engineering like welding.

Research Programme Surfaces and Materials

- Fundamentals of functional films
- Reactive processes during deposition of SiOx thin film using a non-thermal plasma jet at atmospheric pressure
- Low friction hydrophobic hybride films

Research Programme Process Monitoring

- Fundamentals of plasma chemistry – Plasma surface interaction in molecular plasmas
- Quantum cascade laser based monitoring of CF2 radical concentration as a diagnostic tool of dielectric etching plasma processes

Research Programme Welding and Switching

- Fundamentals of arcs
- Welding arcs
- Switching arcs
- Spectral control of illumination for accelerated physiological adjustment to shift work

Introduction

Within the EU Framework Programme for Research and Innovation has defined four Key Enabling Technologies (KETs) that will allow European industries to master the future, to retain competitiveness and capitalise on new markets. These KETs are: nanotechnologies, advanced materials, and advanced manufacturing and processing and biotechnology. For all of these KETs, the usage of plasma assisted surface and thin film technologies constitutes a vital step as it creates high-quality coatings and innovative materials with unique surface properties.

The technological area of interest expands from tuning of interface properties, e.g. to control the adhesion over the production of thin films and their structuring to the systematic change in the properties of the materials themselves, e.g. by influencing interface properties in composite materials or attaching catalysts. Process-related advantages of the plasma processes include low thermal load for the components, environmental friendliness, excellent gap penetration, and also a low influence on the bulk material properties along with good suitability for the treatment of chemically inert materials.

For several years, the focus of the Research Programme (i.e. both its former constituents RP 'Surfaces/Thin Films' and 'Catalytic Materials') has been on studying plasmas for optical, mechanical and chemical functional thin films, with the goal of controlling the inner nanostructure of the growing thin films.

Lately, the deposition of dense, functional thin films with a variable chemical structure has been successfully expanded to hybrid structures by incorporating additional metal into the amorphous film.

At atmospheric pressure, fundamental contributions on the local deposition of functional films on the basis of silicon-organic compounds could be made. Solutions to optimize the supply of reactive raw materials and to reduce the gas consumption have been found that contribute to an improved sustainability of atmospheric pressure processes in surface technology (see also OGAPLAS-project). In particular, the reaction chemistry was modelled along with the fluid dynamics and kinetics present in these plasmas. For the experimental characterization, a diagnostic method, laser-schlieren deflectometry, was described for the first time and successfully used to determine the temperature profile in the effluent plasma. These activities are part of the SFB – TR 24 'Complex Plasmas'.l

On account of its inherent research potential, the topic 'Materials and components for renewable energy technologies' has been emphasized widening the activities in such areas as the synthesis of catalytically active materials, e.g. for fuel cells, photochemical water splitting and photosensitive films for photovoltaic cells.

A key topic in recent years has been the deposition of titanium dioxide films with applications as biomaterial, photocatalytic material, optical element and as the basis for the development of structures for the light-driven and thus renewable production of hydrogen.

Within the framework of the cooperative research project (PluTo^{plus}), for the first time an improved method for control of thin film growth by an active process control is established. This novel process control obtains its signals from variables derived directly from plasma parameters. Considerable improvement in reproducibility and precision are demonstrated with impact on the production of high-quality thin film systems and structured optical surfaces for precision optics such as laser mirrors with high reflectivity and interference filters.

Application potential

Functional coatings with plasma CVD

- Increased scratch resistance
- Control of the gas permeability
- Corrosion protection
- Hydrophobic tribological films

Optical films by PVD and ion-beam-assisted plasma processes

- Optical filters, mirrors
- Anti-reflective coatings
- Photo-catalytic films

Plasma chemical surface functionalization

- For different materials: polymers, metals, dielectrics (also heat-sensitive materials)
- Production of hydrophilic/hydrophobic surfaces
- Bonding properties and printability of chemically inert materials (composites, plastics, CFK, GFK, metals)

Innovative catalysts

- For fuel cells
- For heterogeneous chemical catalysis
- For sensor technology

Components for the use of regenerative energy

- Catalysts for light-driven water-splitting
- Gold and silver nanoparticles for plasmon resonance-enhanced hydrogen production
- Precious metal films for the anodic oxida-tion of $NaBH_4$
- Nanostructured precious metal catalysts
- Electroactive metal polymer films

CONTACT

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Surfaces and Materials
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foest@inp-greifswald.de

Projects:

- Fundamentals of functional films
- Reactive processes during deposition of SiOx thin film using a non-thermal plasma jet at atmo-spheric pressure
- Low friction hydrophobic hybride films

Fundamentals of functional films (core-funded project)

Problem

Low-temperature non-equilibrium atmospheric pressure (AP) discharges have found an increasing number of applications based on various plasma enhanced chemical vapor deposition (AP-PECVD) techniques. In order to achieve high-quality functional coatings with the desired properties the chemical composition of the growing film should be controlled at molecular level. An existing structural deviation of the film in lateral direction e.g. can provoke unintentional spatial inhomogeneity and thus impaired quality (density, pin-holes, refractive index changes etc.). Acknowledging the fact that this can be prevented by improved and well-characterized plasma sources, the need to appropriate diagnostic methods arises. One key parameter is the gas temperature profile as it affects the energetic balance, local particle density and therefore any reaction rate.

Problem-solving approach

AP-PECVD processes are conducted using a non-thermal, miniaturized plasma jet at 27.12 MHz for the deposition of SiOx films. The gas temperature within the single discharge filaments is determined with high spatial and temporal resolution using Laser Schlieren Deflectometry (LSD), a method originally applied by INP for monitoring discharge filaments. An optical ray is deflected by hot spots with unknown temperature. The deflection of the ray by a cylindrically symmetric temperature profile is evaluated.

Technological benefits

The local development of the neutral gas temperature in filamentary plasmas with sub-mm dimensions and steep gradients of the temperature field require high-speed measurements in microscopic dimensions. These requirements are met exceptionally by the LSD-method.
With the characterized source, coatings in a previously unknown quality with respect to lateral homogeneity and a controllable chemical composition are deposited for applications such as passivation film systems for complex (3D) components (e.g. sensors), permeation barriers or for corrosion protection. Nanostructured films are relevant as surfaces for the heterogeneous catalysis.

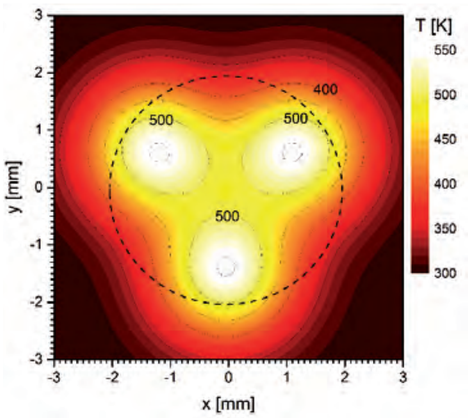
Results

The source is operated in a discharge regime (locked mode) that is beneficial for the controllability of the film properties. The film deposition experiments are accompanied by a 2-dimensional fluid model that permits a combined description of the plasma formation, gas dynamics and thin film formation.

Among other findings, it could be demonstrated for LSD that a universal relation exists between the relative maximum temperature of the filament core (T_1/T_0) and the maximum deflection angle δ_1 of the laser beam: $T_1/T_0 = (1-\delta_1/\delta_0)^{-1}$, where δ_0 is a configuration parameter.

Plans for 2016

- Experimental investigation on the temperature field of a non-thermal jet plasma
- Enhanced spatial resolution by application of a laser with shorter wavelength
- Simulation of helical discharge filaments
- Investigation of the deposition of nanostructured films with applications for heterogeneous catalysis
- Combined PE-CVD and PVD to incorporate metal particles into the polymer matrix



Dynamic temperature field of the effluent perpendicular to the axis of the plasma jet directly below the nozzle Visible are three discharge filaments as reconstructed by LSD. Dashed line marks the inner wall of the nozzle. The period of the pattern rotation is 30 ms.

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Project partner:
University of Brno

Reactive processes during deposition of SiOx thin film using a non-thermal plasma jet at atmospheric pressure

(sub-project of OGAPLAS: DFG/AIF Cluster „Optimization of gas utilization for atmospheric pressure plasma processes")

Problem

Despite their high technological and economic potential, plasmas at atmospheric pressure have been established in surface and thin film technology only for very limited processes to date. One reason is a lack of understanding of the complex processes in the gas phase and at the interface to the surface. Actual process users disapprove the comparatively high gas consumption, the insufficient precursor utilization and poor reproducibility.

Problem-solving approach

In the sub-project of the DFG/AIF Cluster Ogaplas, the plasma properties of a non-thermal plasma jet operating under atmospheric pressure are characterized. The plasma-chemical reaction pathways for the usage of hexamethyldisiloxane (HMDSO) as raw material for the deposition of SiO_x films are illuminated by analyzing the volume and surface reactions that lead to film deposition. A hydrodynamic model is established and the results are considered in relation to the chemical composition and structure of experimentally obtained SiO_x films.

Technological benefits

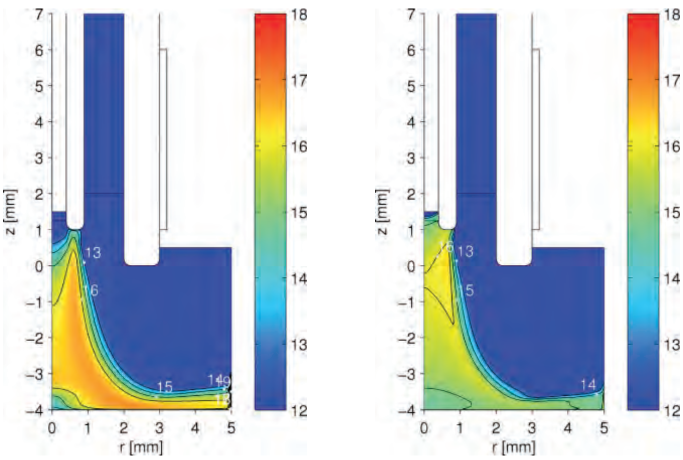
These studies are performed to support the dissemination of this technology and to support associated market opportunities. Coating processes that produce silicon-based films with desired film properties are beneficial for enhancing the adhesion between composites, act as permeation barriers or prevent corrosion. The potential areas of application for AP plasma processes range from electronics to automotive manufacturing, photovoltaics, precision engineering, biotechnology, plastics, and optics.

The optimized process has a positive effect on the resource efficiency as it reduces the gas consumption and the usage of raw materials (e.g. thin film precursors)

Results

A hydrodynamic model of the reactive plasma jet has been developed, that describes the influence of the gas flow and spatially inhomogeneous gas temperature on the primary argon plasma, along with the precursor reactions in the effluent and their transport to the substrate. The calculated gas temperature in the active zone reaches maximum values of about 1400 K. These maximum values are obtained in the center of the discharge filaments and axially somewhat below the center between the electrodes, because of the convection.

The central temperature of the effluent is calculated to 1100 K. Ar_2^+ represent the most abundant ions in the active zone and primarily cause the precursor fragmentation. The calculated radial profiles of the particle flow towards the substrate are in agreement with the measured deposition profiles. By insertion of microprobes into the effluent, the chemical composition of the film could be measured depending on the deposition conditions and substrate position.



Result of hydrodynamic model: Density of neutral (left) and charged (right) reaction products at target region

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Funded by:
German Federal Ministry of Education and Research (BMBF)

Low friction hydrophobic hybride films

Problem

The production of thin functional layers by plasma assisted deposition techniques is widely used in industrial scale, well-known are e.g. hard coatings on tools or surfaces with low friction. Problematic are components where those properties: low friction and hydrophobicity are required at the same time while maintaining an excellent abrasion resistance.

Problem-solving approach

These in part contradicting requirements for industrial surfaces were approached by the deposition of hybrid layer systems. Such multi-component and multi-layer hybrid coatings are typically prepared by deposition of amorphous hydrocarbon (a-C:H) coatings that are tailored to the requirements by incorporation of other chemical elements into the growing film.

The investigations were performed using a capacitively coupled pulsable rf discharge (13.56 MHz). The substrates were positioned on the driven rf electrode which could be heated (up to 400°C) and dc-biased. Hydrocarbons like C_2H_2 or C_2H_4 were added to the Ar-discharge to produce the required a-C:H coatings. Hybrid coatings were achieved by adding Si- or Cu-containing monomers to the gas mixtures.

Technological benefits

The obtained results lead to considerable improvement of the hydrophobicity of metal surfaces while being resistant against mechanical abrasion. This opens up potential applications for mechanical components that are subject to enhanced abrasive forces while they need to stay dry under wet environment. Applications are e.g. coatings for printer parts or stencil plates. The PE-CVD plasma technique allows to produce such hybrid coatings in one process step.

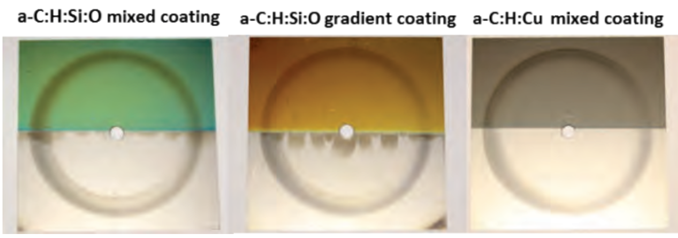
Results

Best results regarding abrasion resistance and washing stability were found using Ar-C2H4 discharges. The addition of hydrogen decreased the deposition rate only but did not improve the coating properties.

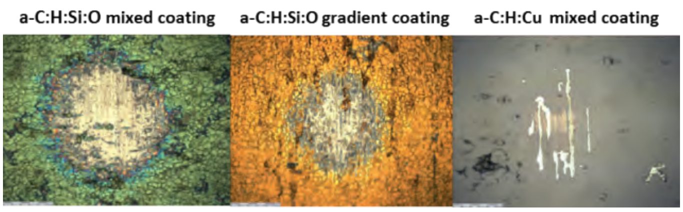
The adhesive strength of a-C:H coatings on steel can be improved significantly by an interface layer of SiO_x. Without such an interface layer the maximum thickness of abrasion-resistant coatings was about 120 nm. The interface layer allows an increase of the functional thickness to 300 nm.

Further improvement of the abrasion resistance was achieved by reduction of the residual coating stress due to incorporation of Silicon into the film. Such hybrid coatings were formed either by alternating monomer deposition or by successively changing the percentage of silicon in the source gas mixture to deposit gradient coatings.

Furthermore, by addition of Cu(II)-acetylacetonate hybrid a-C:H:Cu-coatings could be deposited. The Cu-percentage was determined to 10 at.% (XPS) and improved abrasion resistance compared to standard a-C:H-coatings was found.



Comparison of abrasion tests of various hybrid coatings (TABER Industries abraser 5135, CS-5, 250g, 2000 rounds)



Comparison of ball cratering tests of various hybrid coatings

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Introduction

The focus of the Research Program Process Monitoring is on the investigation of (i) fundamental phenomena and (ii) the technological potential of interactions between plasmas and surfaces. An important scientific topic is the improved understanding of chemical phenomena in molecular plasmas by the application of highly sensitive diagnostic methods, particularly the kinetics of transient molecules. A comprehensive understanding of the reaction kinetics and dynamics that occur at the plasma interface, i.e., where the plasma comes in contact with condensed matter, becomes increasingly important whereby the transition from low pressure to atmospheric pressure plasmas is systematically performed.

The present work, carried out in multiple international scientific cooperations, has tremendous relevance not only for the plasma assisted surface treatment, but also for the monitoring of technological plasmas as well as for process controlling in industry. In addition, plasma diagnostic methods are continuously being developed, which are advantageous to study, e.g., plasma assisted deposition and etching processes, but which also have the potential to be used in semiconductor and surface treatment industry and for trace gas detection in a wide variety of applications such as breath gas analysis and environmental monitoring.

Application potential

Investigating the role of plasma stimulated solid surfaces

- Development of improved plasma nitriding processes
- Plasma assisted surface etching using low pressure plasmas
- Optimization of the chemistry of atmospheric pressure discharges in contact with surfaces

Analysis of the chemical behavior of molecular compounds in plasmas and gases

- Plasma technology (e.g. plasma treatment in the semiconductor industry, deposition of Si-based films in the solar industry)
- Workplace and environmental monitoring
- Reduction of harmful reaction products

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Projects:

- Fundamentals of plasma chemistry – Plasma surface interaction in molecular plasmas
- Quantum cascade laser based monitoring of CF2 radical concentration as a diagnostic tool of dielectric etching plasma processes

Fundamentals of plasma chemistry – Plasma surface interaction in molecular plasmas (core-funded project)

Problem

High-quality synthetic diamond film deposition, which can be used for widespread applications, has been in the center of fundamental and technical studies for more than two decades. Microwave plasma assisted vapor deposition (MPACVD) processes using hydrocarbon–hydrogen feed gas mixtures have been proven to be efficient for the deposition of different crystallinity types of diamond layers. Recently, it was shown that films doped with boron have great potential not only for applications in electronic and optical devices, but also in biology and for biosensing. An understanding of the complex chemistry in $H_2/CH_4/B_2H_6$ plasmas is of general importance for further improvements in doped-diamond deposition technology.

Problem-solving approach

The addition of diborane (B_2H_6) to the standard hydrogen–methane feed gas mixture for doped diamond deposition, and therefore the increasing complexity of the plasma, as well as the influence of surface processes, leads to the necessity to acquire quantitative information, particularly about absolute concentrations, of molecular species in the ground state which can be provided by non-intrusive in situ plasma diagnostic techniques [1]. These plasmas have been studied by infrared laser absorption and optical emission spectroscopy (OES) techniques. The experiments were carried out in order to analyze the dependence of the plasma chemistry on several parameters in the microwave discharges, such as power, pressure and gas mixture, at relatively high pressures up to 300 mbar, and power values up to 4 kW.

Technological benefits

The understanding of optimized microwave plasmas supports the deposition of high quality boron doped diamond while ensuring a high growth rate. The present study improves the understanding of the underlying phenomena of plasma-surface interactions.

Results in 2014/15

The study has led to new insights into fundamental chemical phenomena in microwave (MW) H_2 plasmas with admixtures of methane and diborane which are used for the deposition of thick high-quality synthetic diamond films. The experimental arrangement is shown in figure 1. Besides the detection of six atomic and molecular excited species the boron atom ground state concentration in the plasma for a couple of parameters, i.e., power, pressure and gas mixture could be derived. An overview of the main produced species in the plasma processes was achieved by using the in situ TDLAS technique combined with an OES spectrometer. The concentrations of the main molecular products were in a range of more than three orders of magnitude. Part of these new results can be seen in figure 2.

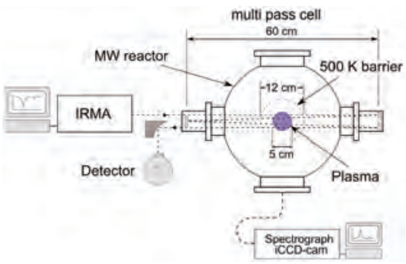

Figure 1. Experimental arrangement of the MW reactor combined with the TDLAS system (IRMA) and the OES unit [1].

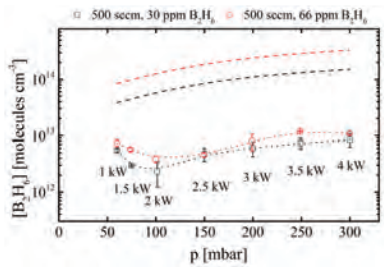

Figure 2. Concentration of B_2H_6 depending on pressure and power, given by the inserted values, for different admixtures of B_2H_6 to the hydrogen feed gas. The injected amounts of B_2H_6 are given by the dashed lines [1].

[1] S. Hamann, C. Rond, A. V. Pipa M. Wartel, G. Lombardi, A. Gicquel, and J. Röpcke,, Plasma Sources Sci. Technol. 23 (2014) 045015.

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Quantum cascade laser based monitoring of CF_2 radical concentration as a diagnostic tool of dielectric etching plasma processes (industrial project)

Problem

The ongoing enhancement of integrated circuits performance is still following Moore's law. So far, the focus has been on shrinking of the feature sizes to maximize the transistor density. To further improve the performance, the next step is a further reduction of parasitic interlevel and intralevel capacitances by using low-k dielectrics, i.e., a material with a smaller dielectric constant than silicon dioxide. Dielectric etching plasma processes for modern interlevel dielectrics become more and more complex by the introduction of new ultra low-k dielectrics. One challenge is the minimization of sidewall damage, while etching ultra low-k porous SiCOH by fluorocarbon plasmas. The optimization of this process requires a deeper understanding of the concentration of the CF_2 radical, which acts as precursor in the polymerization of the etch sample surfaces.

Problem-solving approach

In an industrial dielectric etching plasma reactor, the CF_2 radical was measured in situ using a continuous wave quantum cascade laser (cw-QCL) around 1106.2 cm^{-1}. The Doppler-resolved ro-vibrational absorption lines were measured and the absolute densities using transitions in the ν_3 fundamental band of CF_2 could be determined with the aid of an improved simulation of the line strengths.

Technological benefits

The understanding of optimized radio frequency plasmas supports the etching of high quality semiconductor circuits. The present study improves the understanding of the underlying phenomena of plasma-surface interactions.

Results in 2014/15

It was found that the CF_2 radical concentration during the etching plasma process directly correlates to the layer structure of the etched wafer. Hence, this correlation can serve as a diagnostic tool of dielectric etching plasma processes. Applying QCL based absorption spectroscopy opens up the way for advanced process monitoring and etching controlling in semiconductor manufacturing. Part of these new results can be seen in figure 2 [1].

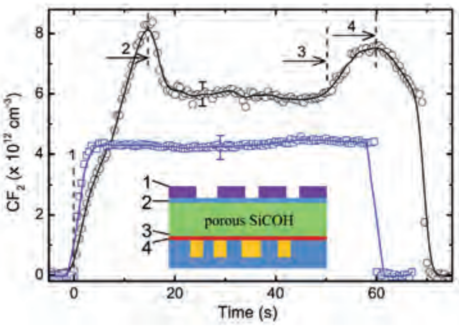

Figure 1. Outline of the Oxford Plasmalab System 100 ICP etch chamber equipped with Q-MACS Process fibre system. CF2 radicals were detected using a multipass cell just above the wafer. [1].

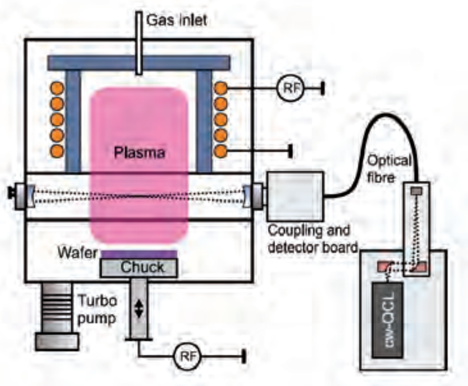

Figure 2. Time dependent CF_2 concentration while etching blank porous SiCOH (squares) and structured porous SiCOH (circles) using a CF_4 plasma with a rf power of 1000 W, bias power of 60 W, 1.33 Pa total pressure, and a gas flow rate of 25 sccm. The inset shows a schematic diagram of the lateral cross-section of a structured porous SiCOH wafer [1].

[1] M. Hübner, N. Lang, S. Zimmermann, S. E. Schulz, W. Buchholtz, J. Röpcke, and J. H. van Helden, Appl. Phys. Lett. 106 (2015) 031102.

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Introduction

The research programme Welding and Switching is focused on studies of thermal plasmas and their technological applications. Experimental and theoretical research work supports the application of arc plasmas in switchgears of high-, medium- and low-voltage networks as well as in various branches of production and process engineering such as arc welding, plasma welding, hybrid welding, plasma cutting and coating. Furthermore, the existing expertise in the diagnosis and characterization of the light sources is successfully used in studies of biological aspects of general lighting.

The understanding of the basic physical processes in the arc plasma and its interaction with surrounding materials relevant for respective application is the core of the research programme.
Detailed knowledge of the arc properties and dynamics and their control mechanisms deliver new advanced diagnostic and control methods and allows for the derivation of new approaches for process improvement.

In particular, advanced optical diagnostics methods have been developed and adopted for specified applications. The studies have been performed on both model systems and real processes. The experimental diagnostics is supported by numerical simulation and modelling. Appropriate models for the arc plasma or its specific regions as well as complex procedures for the simulation of arc applications are being developed. Numerical simulations help to accelerate the development of devices and reduces the corresponding costs.
The research programme primarily contributes to the development of plasma applications which possess significant potential for energy-saving technologies, safe energy distribution, as well as costs and energy efficient processes. In addition to improvements of the performance characteristics, including efficiency, process safety and lifetime of the systems, also environmental aspects and avoidance of health-damaging effects are under detailed investigations. An example are the stronger requirements for reduction of harmful emissions in arc welding and switching applications. Also the studies in the field of light sources devoted to the aspects of health and human well-being that play, for instance, a special role

Application potential

The research methods for process improvement and the implementation of new approaches developed in the research programme can be used in many applications of plasma-based production and process engineering, like e.g.

- arc welding processes
- plasma welding processes
- plasma hybrid welding processes
- plasma torch for cutting, spraying and plasma-assisted vapour deposition technology

Effective energy dissipation in the arc plasmas are widely used in such applications of electrical engineering as switchgears. The simulation and diagnostics of switching arc plasmas supports

- development of circuit breakers in low-, medium- and high-voltage technology
- development of approaches for new arc extinguishing principles
- reduction of environmental impact

Long-time experience in the characterization of the light sources supports the development of radiation sources for general lighting and special applications, taking into account the biological effect on human health and safety by influencing the human factor.

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Projects:

- Fundamentals of arcs
- Welding arcs
- Switching arcs
- Spectral control of illumination for accelerated physiological adjustment to shift work

Fundamentals of arcs (core-funded project)

Problem

Thermal plasmas are the essential component in electrical engineering applications, particularly in switching devices in low-, medium- and high-voltage networks, as well as in many areas of process engineering, including arc welding, plasma welding, hybrid welding and plasma cutting. Despite established technologies and long-time research work, the detailed knowledge about the properties and physical mechanisms of the arc is still missing. This hinders technological innovations based on detailed understanding of the physical processes. Advanced models which include detailed description of all relevant processes give the missing information and corresponding knowledge. These models and approaches must be validated in experiments with sufficient accuracy. Advanced diagnostics approaches which give a detailed information about specific arc plasma properties, like e.g. temperature, composition, pressure and velocity are, therefore, necessary for characterization of the arc plasma and its periphery.

Problem-solving approach

A strengthening of the coupling between modelling and experiment is achieved by putting into service the arc research laboratory. The laboratory equipment allows for detailed experiments using optical diagnostics on free-burning arcs, plasma-wall and plasma-electrode interaction, and switching arcs in vacuum. Continuous improvement of non-equilibrium models, particularly by taking into account departures from thermal, chemical and ionization equilibrium leads to close agreement between theory and experiment and, therefore, to the development of efficient and realistic simulation tools which can be used for design and parameter optimization.

The existing optical diagnostics methods for determination of plasma temperature and species densities are extended and used for the analysis of the time-dependent spatially inhomogeneous plasma including the regions close to the electrodes and the walls.

Technological benefits

Application of quantitative measurements and experimentally validated models leads to deeper understanding of the physical processes and generates new approaches for optimized or novel process management. Simulations reduce the design and development costs of the devices and system components.

Scientific Results in 2014/15

- Improvement of MHD model, taking into account the arc-cathode interaction, deviations from thermal equilibrium and collisional-radiative model with advanced description of resonance radiation transport for free-burning arcs in argon
- Adoption and application of optical diagnostics methods for time- and space- resolved determination of temperature in the plasmas of switching arcs
- Development of time and space resolved optical diagnostics approach based on combination of emission spectroscopy and high speed cinematography (high speed video spectroscopy)
- Analysis of plasma-wall interaction in free-burning arcs
- Development of improved black-box arc models based on the arc diameter and averaged arc energy balance

Plans for 2016

Arc diagnostics will be further improved in order to better resolve the spatial structure and temporal evolution of the arc column and regions close to the electrodes and walls. The experimental basis for the investigation of high current arcs will be further expanded. Models for thermal plasmas with deviations from the equilibrium will be improved with regard to the special aspects of arc-anode interaction and electrode erosion.

High-current generator in the arc research laboratory

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Project partners:
UniBw Munich

Welding arcs (third-party funded project)

Problem

Besides widely applied arc welding processes like e.g. gas metal arc welding (GMAW) and tungsten inert gas welding (TIG), advanced material processing methods like laser assisted (hybrid) welding and submerged arc welding are used in metal processing. These processes have a reduced accessibility for quantitative arc diagnostics due to significant deviations from symmetry or covered process zone. Conventional welding processes require noticeable innovations in order to remain competitive as a cost-effective joining technology considering new materials and increased quality requirements. Furthermore, the process safety and efficiency are the necessary features for modern technologies. Such innovations can be achieved only on the basis of a detailed understanding of the mechanisms of action in the arc that previously did not exist sufficiently.

Solution approach

Qualification of optical diagnostics methods for the measurements on non-symmetric objects and development of corresponding data processing methods is necessary. Here, the tomographic reconstruction is the right evaluation procedure. However, the conventional tomography is not suitable for evaluation of pulsed objects like arc plasma. The method based on the use of several high-speed cameras complementary to OES diagnostics in combination of iterative data evaluation procedure give this possibility.
For optical investigations on submerged arc welding process adapted setup for time and space resolved optical analysis by high-speed imaging (HSI) and high-speed video spectroscopy (HSVS) has been developed. The process becomes optical accessible through a tiny metallic tube which is filled with non-reactive gas at specified pressure.

Technological benefits

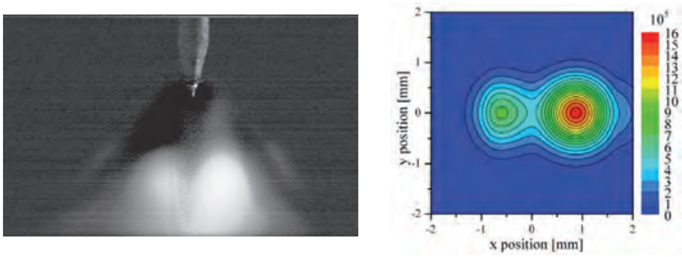
The results from the research on the fundamentals have been used for further development of innovative process concepts such as laser-assisted arc welding and submerged arc welding. Increase the stability and process reliability, as well as the efficiency of the welding process are added values through research.

Results in 2014/15

- Development of 3D tomography method for analysis of non-symmetric arc plasmas
- Determination of 3D temperature and conductivity profiles of a TIG arc disturbed by laser radiation
- Development of optical accessibility method for SAW process
- Detailed information from HSI about SAW process about arc and powder dynamics, flux interaction with liquid metal, slag building
- Detailed information from HSVS about SAW process about species in plasma (alloying up of steel), acquisition of data for temperature estimation

Plans for 2016

- Improvement of non-equilibrium models for simulation of welding processes by detailed comparison between different collisional radiative models
- Development of optical methods for quantitative characterization of submerged arc welding process



High-speed image of .argon TIG arc disturbed by CW laser with λ=811 nm(left) Resulting conductivity distribution in the central plane (right)

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Funded by:
German Research Foundation - Alliance for Industrial Research (DFG-AIF)

Project partners:
Laser Centre Hanover,
Fraunhofer IPA Rostock

Switching arcs

Problem

Thermal plasma represents the essential functional component in a numerous applications involving the electrical power supply and energy distribution. Detailed analysis and deeper understanding of the basic plasma processes is the basis for further development and optimization of arc-based switching devices. Switching performance at high electrical currents at all voltage levels (low, medium and high voltage) requires the safe operation of power system components. The development of switching devices at up-to-date technical level taking into account environmental aspects is no longer conceivable without physical modelling of the functional component plasma and accompanying experimental studies.

Solution approach

Complex arc dynamics make special demands on diagnostic methods. For the analysis of such objects, combinations of optical emission spectroscopy (OES) and high speed cinematography are used.
Strong electrode and wall erosion was observed in the switchgears under realistic working conditions. At such conditions the emission spectrum of the plasma during the active phase is dominated by radiation of electrode and nozzle material. During the ignition phase and close to the arc extinguishing (current zero) the radiation of gas is present. For the determination of plasma parameters, like e.g. temperature and composition, combination of complementary OES methods, like e.g. analysis of atomic and ionic line radiation and video spectroscopy have been developed as a general solution approach, allowing for the study of broader spatial regions and extended temporal ranges.

Technological benefits

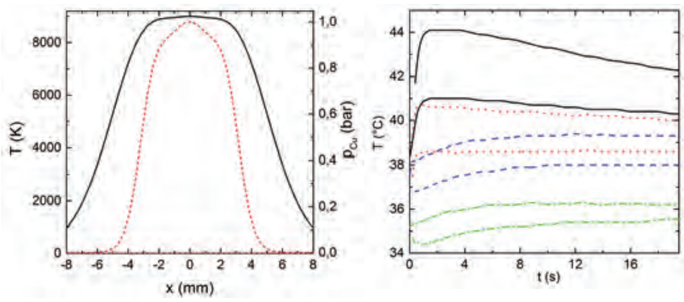
The novel diagnostic methods of arc plasma lead to a deeper understanding of the physical processes and as a consequence to development of improved switching concepts and operation principles. The use of such methods for parameter and design optimization saves significantly time and costs in the development of switchgears.

Results in 2014/15

- Successful transfer of OES methods to investigations of vacuum arcs
- Determination of time-resolved axial distributions of charged states in diffuse vacuum arcs
- Application of spectra simulation method for determination of absolute temperature and temperature profiles for metal-dominated optically thick plasma of free-burning arcs in air
- Temperature determination in axially blown switching arcs by combination of various methods based on optical emission spectroscopy for the arc column and the arc mantle
- Study of plasma-wall interaction on example of protective ceramic layers in front of free-burning arc by video spectroscopy, thermography and high speed cinematography

Plans for 2016

- Transfer of existing time-and space-resolved optical diagnostic methods, e.g. video spectroscopy to vacuum arcs
- Characterization of metal vapour diffusion and the erosion behaviour in vacuum switches during the post-arc phase under variable conditions
- Development of unified black-box model for arc simulations in a broad parameter range
- Adaptation of laser absorption spectroscopy to diagnostics of arc plasmas



(Left) Temperature and Cu pressure profiles in a free-burning Cu dominated arc

(Right) Temporal evolution of substrate temperature for coatings with $MgCO_3$ (black, blue) and $CaCO_3$ (red, green) and different binder - organic (black, red) and plaster (blue, green)

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Spectral control of illumination for accelerated physiological adjustment to shift work (third-party funded project)

Problem

Night shift work is in contradiction with normal circadian rhythmicity. It requires a high working activity at the time with lowest motivation while the rest period must take place when the motivation to work is high. The repetitive chronodisruption is harmful to the health and can lead to various dangerous diseases, like mental disorder, depression or cancer. It is known that artificial lighting has a positive impact on security and prosperity and leads to an improvement in the quality of life. Particularly, it has an impact on melatonin synthesis in human body and, hence, can influence the circadian rhythmicity. Previous studies have clarified that monochromatic blue light has much stronger impact in comparison with monochromatic red light. However, the monochromatic light is not suitable for workplace lighting. The aim of the project was to investigate the ability of polychromatic white light sources to influence the melatonin synthesis via changes in spectral characteristics and, therefore, to regulate the adaption for the night shift work.

Solution approach

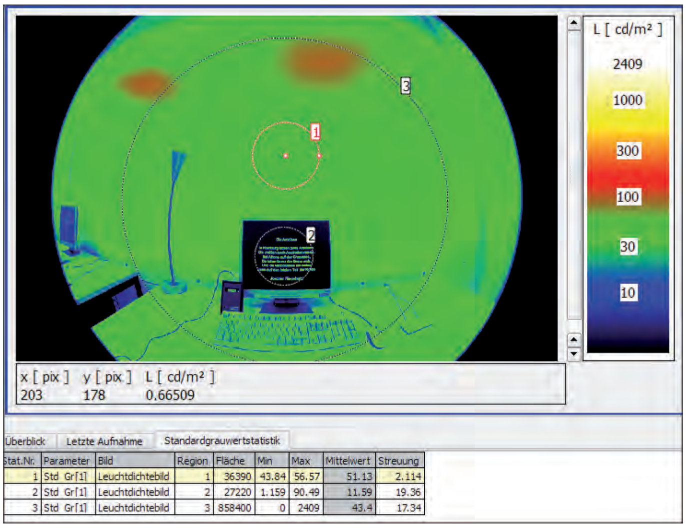
Within the framework of the joint project funded by the German Research Foundation (DFG), biological investigations at IfADo Dortmund were accompanied by lighting investigations in INP Greifswald. Different types of spectral distributions were studied – with expected weak and strong suppression of melatonin production. Such spectra could be applied to a different number of night shifts. Qualified spectral distributions were then realized using commercial light sources. The light sources with different colour temperature from 1600 K to 19000 K and constant luminance of 200 lx were tested for lighting in special test rooms on a group of volunteers. Evaluation was done using subjective impressions (sleepiness), chemical analysis (melatonin in saliva) and repetitive concentration tests for visual performance.

Social impact and technological benefit

The knowledge about suitable lighting during the night work makes it possible to limit the negative physiological, psychical and health impacts and improves the life quality of concerned persons. The project gives rise to the development of future sustainable lighting concepts for working environment which support the human wellbeing and improve the safety during the night shift work.

Results in 2014/15

Among all possible light sources two lamps have been identified for detailed studies: one with 2750 K (warm white - WW) and one with 14000 K (cold white - CW). Sources with colour temperature below 2000 K are not suitable due to poor colour discrimination. The tests were performed in following order: in case of short night work – first WW then CW, in case of long working period first CW than WW. The analysis clarifies that the change of colour temperature only is not sufficient for significant shift in circadian rhythmicity. In addition to this measure the luminance should be adjusted. Prevention of chronodisruption by preserving the melatonin production seems, therefore, possible with light sources with colour temperature less than 3000 K.



Luminance of experimental working place for night shift work in false colour presentation.

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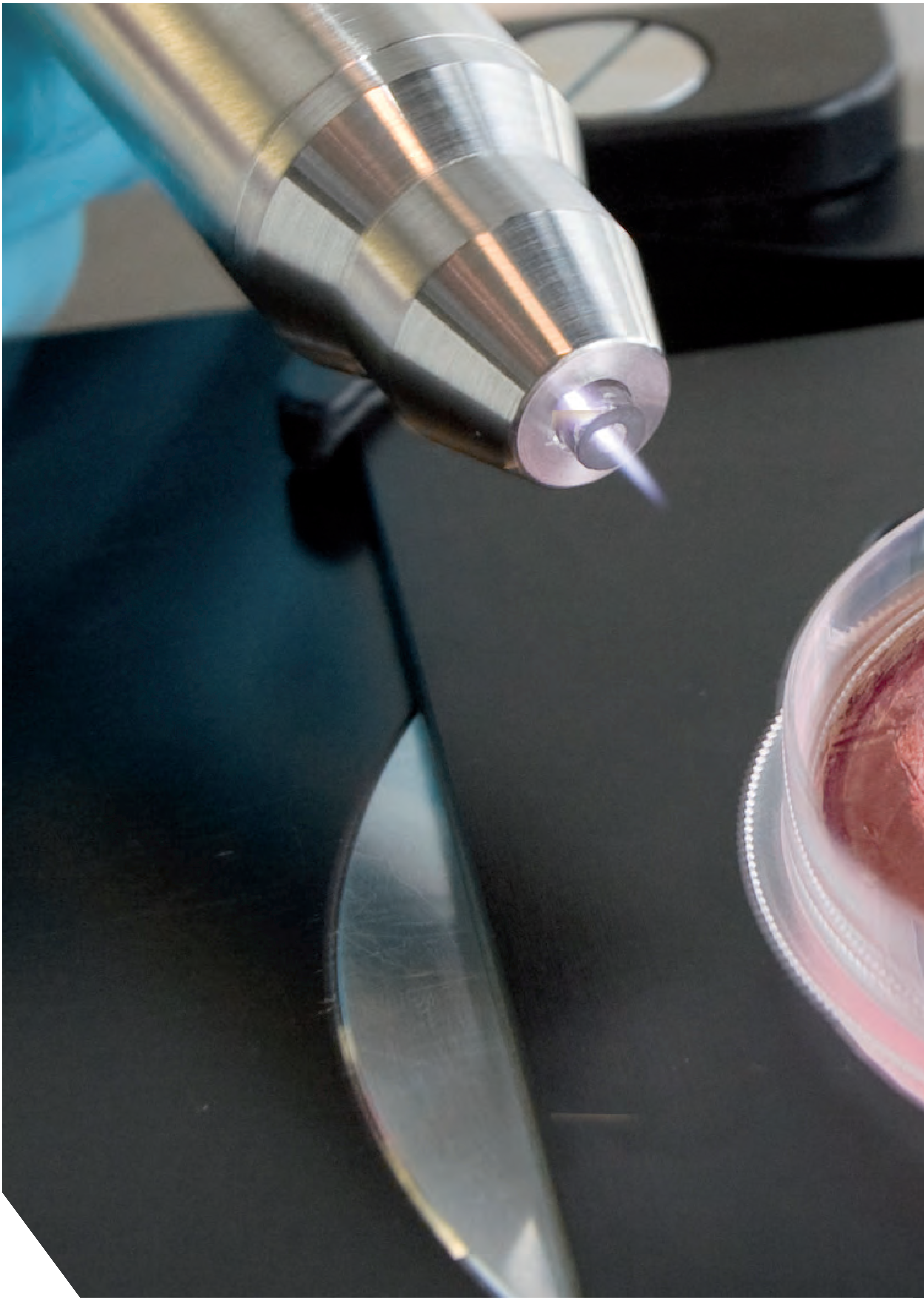
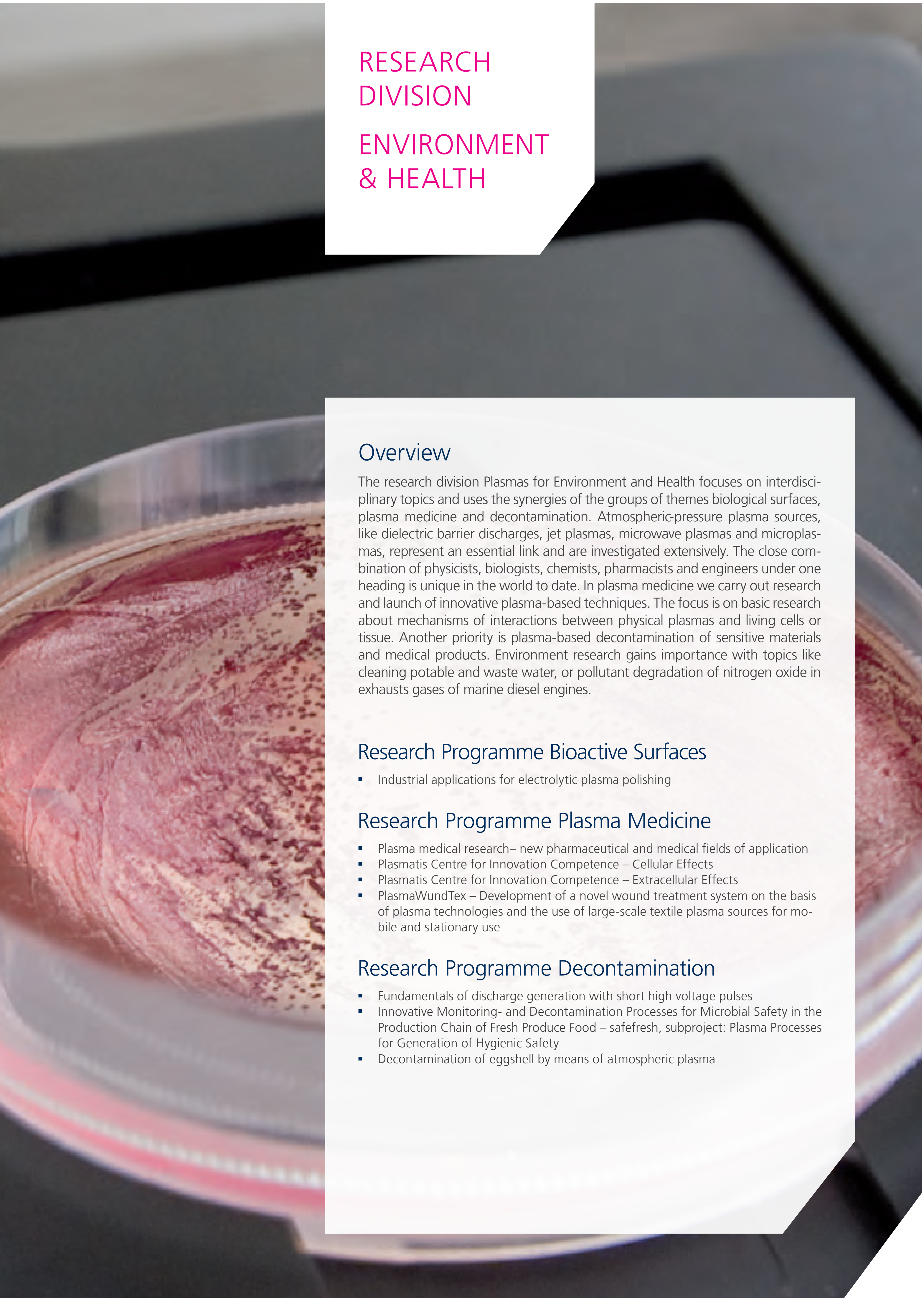
Funded by:
German Research Foundation (DFG)

Project partners:
IfADo Dortmund, INP Greifswald





RESEARCH DIVISION

ENVIRONMENT & HEALTH

Overview

The research division Plasmas for Environment and Health focuses on interdisciplinary topics and uses the synergies of the groups of themes biological surfaces, plasma medicine and decontamination. Atmospheric-pressure plasma sources, like dielectric barrier discharges, jet plasmas, microwave plasmas and microplasmas, represent an essential link and are investigated extensively. The close combination of physicists, biologists, chemists, pharmacists and engineers under one heading is unique in the world to date. In plasma medicine we carry out research and launch of innovative plasma-based techniques. The focus is on basic research about mechanisms of interactions between physical plasmas and living cells or tissue. Another priority is plasma-based decontamination of sensitive materials and medical products. Environment research gains importance with topics like cleaning potable and waste water, or pollutant degradation of nitrogen oxide in exhausts gases of marine diesel engines.

Research Programme Bioactive Surfaces

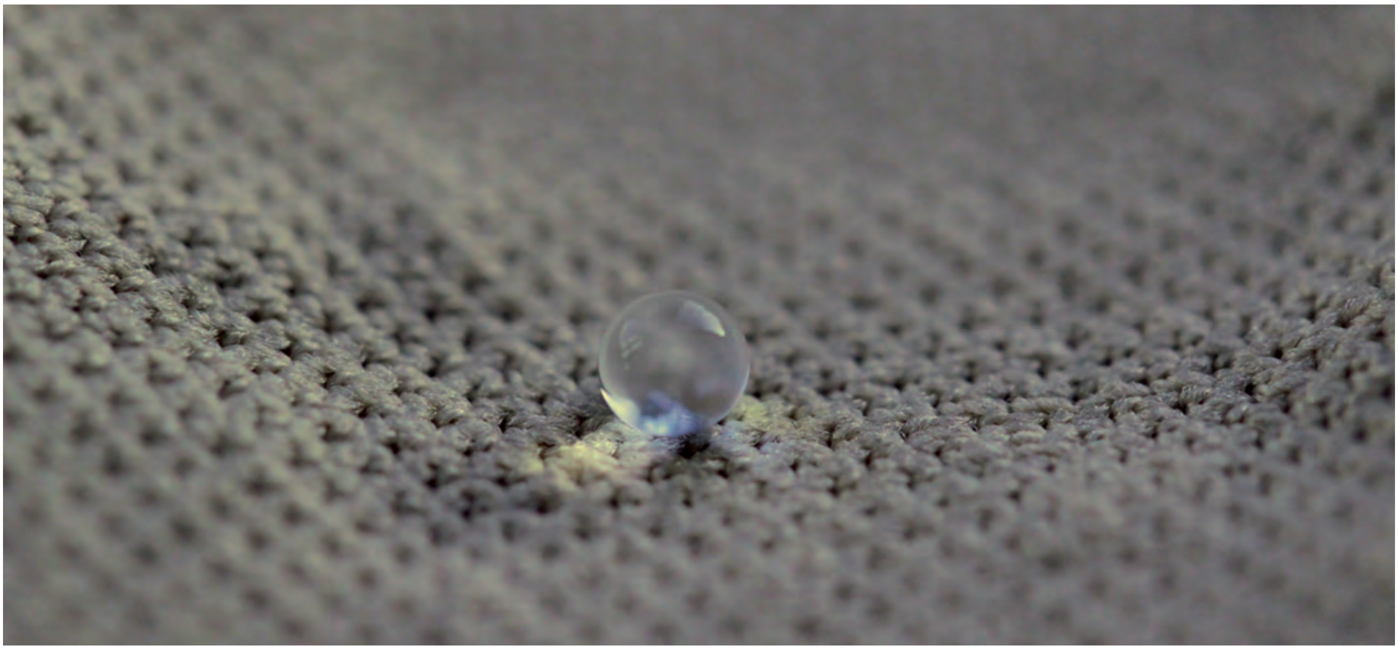
- Industrial applications for electrolytic plasma polishing

Research Programme Plasma Medicine

- Plasma medical research– new pharmaceutical and medical fields of application
- Plasmatis Centre for Innovation Competence – Cellular Effects
- Plasmatis Centre for Innovation Competence – Extracellular Effects
- PlasmaWundTex – Development of a novel wound treatment system on the basis of plasma technologies and the use of large-scale textile plasma sources for mobile and stationary use

Research Programme Decontamination

- Fundamentals of discharge generation with short high voltage pulses
- Innovative Monitoring- and Decontamination Processes for Microbial Safety in the Production Chain of Fresh Produce Food – safefresh, subproject: Plasma Processes for Generation of Hygienic Safety
- Decontamination of eggshell by means of atmospheric plasma



Water droplet on an anti-adhesive coating on a textile used for wound dressing or medical gloves.

Physical plasma processes are preferred for systematic control of the interface properties of different sized, complex shaped products and materials by functionalization in the gas phase and also by deposition of functional coatings, grafting of functional molecules or alloying the surface near region. Respective processes are applied at atmospheric pressure as well as under low pressure. In terms of process reliability and quality assurance plasma processes offer many advantages like low thermal stress for the product and as a consequence a negligible effect on the mechanical properties of the base material, the ability to even enhance surfaces and holes with a high aspect ratio, environmentally friendly processes and, especially for atmospheric pressure plasmas, an easy integration into existing production chains. Due to continuous miniaturization and specialization of products in combination with a desired high durability the demand for plasma processes and sources is increasing.

The Research Program "Bioactive Surfaces" is concerned with the development of plasma-based or plasma-induced processes for the treatment of nearly every material surface (e.g. polymers, metals, ceramics, glass or textiles) that are in direct contact with biological matter. This includes the enhancement of surfaces with cell-adhesive, anti-cell-adhesive or antimicrobial properties as well as their combination. Furthermore, the interaction of surfaces with proteins, like allergens, enzymes or endotoxins, is a key aspect in research and development.

Besides fulfilling high scientific expectations the increasingly application –oriented Research Program is consistently aiming for the transfer of results into industrial applications. For this reason, a variety of plasma systems with a high technological readiness level (TRL) were set up and taken into operation within the reporting period. High purity and defined applications in low pressure were developed through a novel system for the combination of film deposition in the HiPIMS mode with the enrichment of the substrate subsurface with plasma based ion implantation, designed for the homogeneous enhancement of complex-shaped products. In order to find the perfect plasma solution for partners from industry, atmospheric pressure plasmas like jet-plasmas, dielectric barrier discharges, plasma spraying or plasma polishing were build up in 2 highly industrial application laboratories.

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Projects:

- Industrial applications for electrolytic plasma polishing

Basic research

Combination process of High Power Impluse Magnetron Sputtering (HiPIMS) and Plasma Based Ion Implantation (PBII) to generate abrasive resistant antimicrobial coatings

Problem

The adherence of microorganisms on contact surfaces and its persistence for weeks or even months is a main cause of cross-contaminations and spread of infections in healthcare and food processing facilities. The problem is emphasized by increasing the presence of microorganisms that have become resistant to a number of different antibiotics. The infection of surgical wounds by Staphylococcus aureus is a common problem in hospitals and its ability to develop resistance to antibiotics contributes to the danger to patients. Despite hand-washing campaigns and routine cleaning, infection rates remain high. This has raised the need to combat pathogenic microorganisms to lower the risk of acquiring infections. A promising and effective strategy to prevent spreading of microorganisms in hygiene-sensitive areas is the refinement of inanimate surfaces with antimicrobial properties. Among different strategies, are contact-mediated killing metals like copper (Cu) and silver gaining in interest as self-sanitizing material. A further advantage in antimicrobial metals is that small concentrations are already sufficient to significantly inhibit the metabolism of bacteria, and thus achieve high anti-microbial efficacies (e.g., copper is recognized by the united states environmental protection agency (EPA) as being able to continuously kill more than 99.9% of bacteria that cause hospital-acquired infections in 2 h). Since copper-containing proteins are involved in cell metabolism, and, hence, copper in low concentration is an essential trace element in living organisms, there is little risk to patients and consumers. However, abrasion of coatings on medical products is one of the main challenges to face with and one of the main KO criteria for a latter approval.

Approach

HiPIMS allows the deposition of hard metal containing coatings with a high contour compliance. In combination with PBII an additional mixing of the coating with the substrate material is used to increase the abrasion resistance.

Results

In the frame of a project called "Wachstumskern Centifluidic Technologies" (FKZ 03WKCC3A) a special system was designed and assembled to enable the combination process. This system includes a vacuum chamber with an adequate pumping system, two 4" DC magnetrons, a HiPIMS pulsing unit with all associated components connected to the magnetrons and a pulsing unit to apply the PBII pulses onto the sample holder. The pulsing unit for the PBII pulses is triggered by the HiPIMS signal via a delay generator to guarantee defined pulses at a specific phase of the HiPIMS process. The experiments revealed interesting effects. The combination process in comparison to pure HiPIMS shows a significant increase of crystallinity and also an increased sheath thickness resp. deposition rate. Furthermore, due to the mixing of the coating with the substrate material the abrasion resistance could be increased (see Fig. 1). The antimicrobial efficacy strongly depends on the amount of deposited copper on the surface. Values between 1 log and to 5 log reduction are achievable. Thus, a wide range of possible applications from implants over infusion systems op to keyboards or PIN pads can be covered with these kinds of coatings.

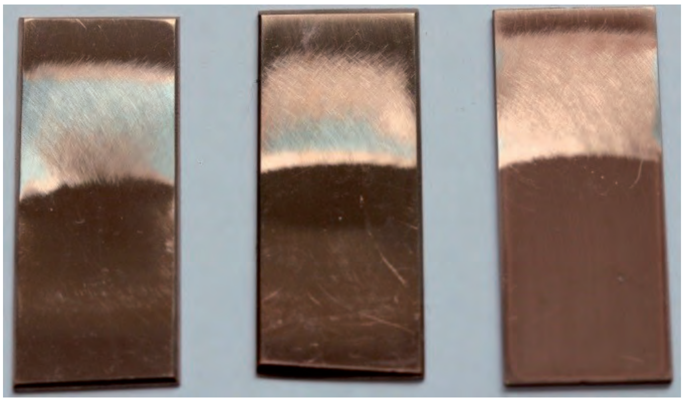

Fig. 1: Honed steel plates (4000er graning) after different coating process with copper. Left: DC sputtering; center: HiPIMS; right: HiPIMS + PBII

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Industrial applications for electrolytic plasma polishing

Problem

In nearly every branch like the automotive industry, aerospace, medical engineering, hydraulics engineering, electrical engineering or mechanical engineering metallic parts made of different alloys are needed and produced. Especially, if these parts are in direct contact with body liquids, oil and fat, dirt, chemicals or even other solid products the quality of the surface is sufficient for its function and durability. Chips, burrs, small particles, oil and other residue from production process can't be avoided. The less crack risers are on the surface and the more closed and smoother the surface is the less corrosion appears. Both resulting in increased process stability and decreased service intervals. Smooth and glossy surfaces are also very important for decorative and aesthetic reasons.

Since decades developers and scientists work on economic processes and technologies to achieve the desired surface qualities. The technical status quo covers e.g. ultra-sonically cleaning, electro polishing, mechanical polishing, scratching or mordanting. All these technologies have their pros and cons but no technology is versatile enough. In most cases a combination of these technologies to achieve the final surface finishing is essential.

Fig. 2: Comparison between untreated stainless steel direct after processing without any cleaning (left) and after electrolytic plasma polishing (right).

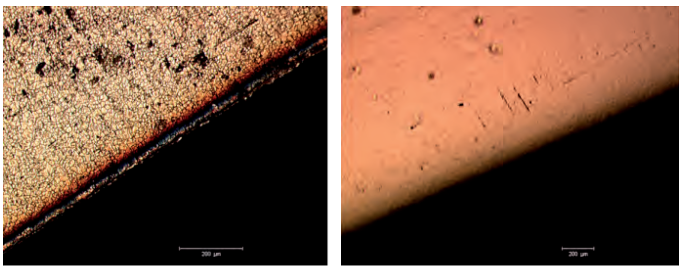

Fig. 3: Comparison of laser cutted edges before (left) and after electrolytic plasma polishing process (right).

Approach

electrolytic plasma polishing is able to combine cleaning, degreasing, deburring und mirror finish polishing in one process step.

Results

In the frame of a project called "Wachstumskern Centifluidic Technologies" (FKZ 03WKCC3A) a special system was designed and assembled to enable the application of electrolytic plasma polishing. In direct cooperation with industrial partners different applications were tested as feasible. As an example the roughness of cold rolled stainless steel was reduced of a factor of 15 down to 6 nm in between 5min process duration. The surface gloss and reflectance is comparable to mechanical polished samples by hand. There is no precleaning step like ultra-sonically cleaning, degreasing or mordantig necessary. Deburring of e.g. laser cutted or drilled samples was accomplished within some seconds process time (see Fig. 3). The process works for stainless steel with a carbon content below 0.5%, Titanium and different alloys, Magnesium and it's alloys as well as for rare metals like copper. Other possible applications are decoating of high tech products with e.g. CrN, CrAlN coatings like drills or increasing corrosion resistance via selective polishing.

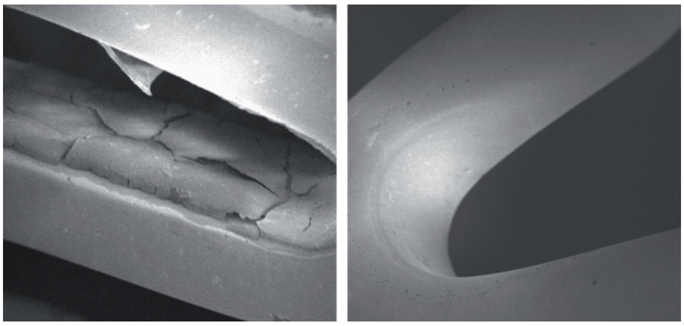

Fig. 4: Removal of coatings. Before (left) and after electrolytic plasmapolishing process (right).

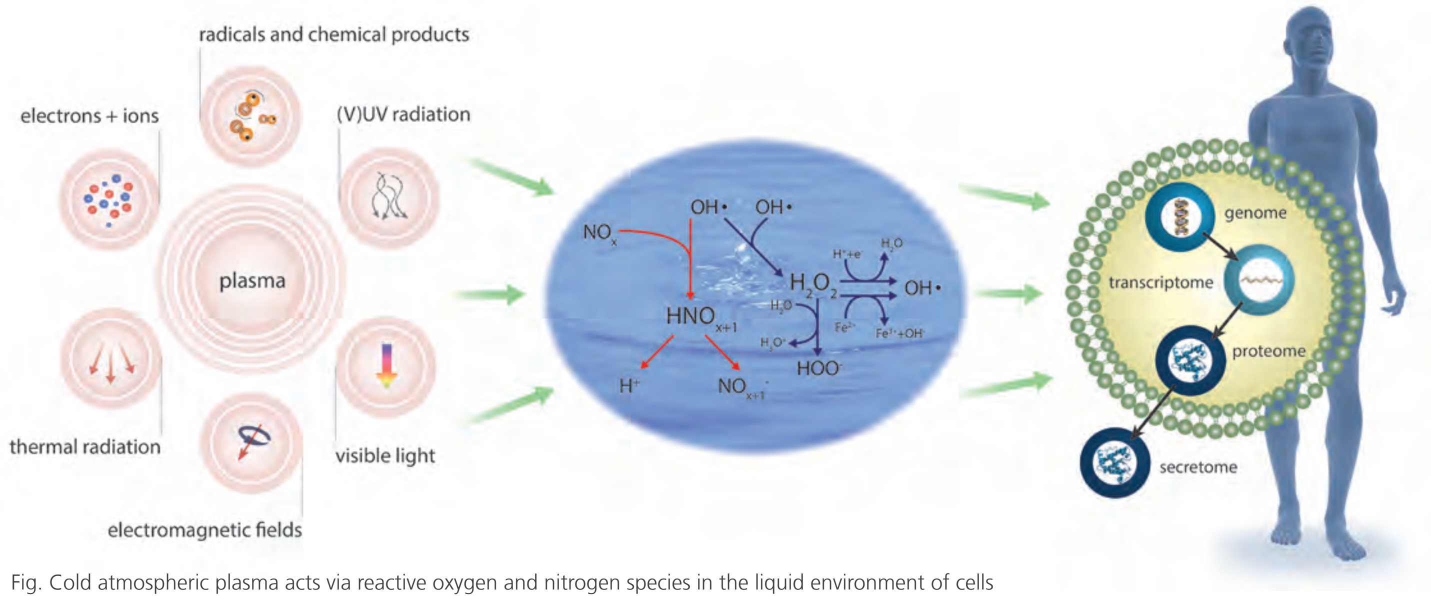

Fig. Cold atmospheric plasma acts via reactive oxygen and nitrogen species in the liquid environment of cells

Introduction

The main task of the INP Research Program Plasma Medicine is to realize basic research and application oriented research in the field of biomedical application of cold atmospheric plasma and to support and organize the transfer of research results both to clinical research and to industrial application. During the last years this research was generously fostered by research grants from the Federal Ministry of Education and Research as well as the Ministry of Education, Science and Culture of Mecklenburg-Western Pomerania.

With this work, INP Greifswald was able to establish itself to one of the world's leading centers of the innovative research field plasma medicine. This was acknowledged by the evaluation of the Leibniz Association in 2014, where the research program (still as research program "Plasma Medicine/Decontamination") was ranked as "excellent". This was among other things motivated by the fact that research outcomes of this research program "set international standards in this young research field". In response to this ranking as well as because of the growing importance of both the research field plasma medicine and the research field plasma decontamination, two separated research programs "Plasma Medicine" and "Decontamination" were started in 2015.

Not least thanks to the systematic basic research mainly realized by the INP-adjunct Centre for Innovation Competence (ZIK) "plasmatis - Plasma plus cell" two fundamental insights on main mechanisms of plasma-cell and plasma-tissue interactions are identified:

- Biological plasma effects are significantly caused by plasma induced changes of the liquid environment of cells, and
- Biological plasma effects are dominated by reactive oxygen and nitrogen species generated in or transferred into liquid phases by plasma treatment.

These fundamental insights are very important both for basic research and for clinical application because

- findings of redox biology can be used to explain and interpret biological plasma effects and to foster future systematic basic as well clinically oriented research, and
- the risk of plasma application in medicine is assessable and manageable because these reactive oxygen and nitrogen species are the same as are acting in regular physiological and biochemical processes inside the human organism.

The highlight of application-oriented research in plasma medicine was the CE certification of the cold atmospheric plasma jet kINPen MED by neoplas tools GmbH in 2013, which was mainly based on INP research effort. Starting with the availability of this certified medical device, clinical plasma application has been growing at first for treatment of chronic wounds as well as pathogen-based diseases of skin.

Based on this and in cooperation with neoplas tools GmbH, several research partnerships with clinics could be opened or consolidated in 2014 and 2015, among others with

- Department for Oral and Maxillofacial Surgery, University Medicine Greifswald
- Klinikum Karlsburg – Herz- und Diabeteszentrum Mecklenburg-Vorpommern
- Department of Operative and Preventive Dentistry, Charité – Universitätsmedizin Berlin

Additionally, the several years-lasting research cooperation with the Surgical Research Laboratory at the Department of General, Visceral, Thoracic and Vascular Surgery of University Medicine Greifswald was consolidated with the founding of an interdisciplinary and inter-institutional research group "Plasma re-surg".

Together with these clinical partners, new application fields of cold atmospheric plasma in oncology, dentistry and cardiac surgery are opened up.

Projects 2014/2015

- Plasma medical research– new pharmaceutical and medical fields of application (2013-2015; funded by Ministry of Education, Science and Culture of Mecklenburg-Western Pomerania and European Union)
- Centre for Innovation Competence (ZIK) "plasmatis - Plasma plus cell", 1st funding period, Junior Research Groups "Cellular Effects" and "Extracellular Effects" (2009/2010 - 2014/2015; funded by Federal Ministry of Education and Research)
- PlasmaWundTex – Development of a novel wound treatment system on the basis of plasma technologies and the use of large-scale textile plasma sources for mobile and stationary use (XXXX-2015; funded by ….)

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Projects

- Plasma medical research– new pharmaceutical and medical fields of application
- Plasmatis Centre for Innovation Competence – Cellular Effects
and Extracellular Effects
- PlasmaWundTex – Development of a novel wound treatment system on the basis of plasma technologies and the use of large-scale textile plasma sources for mobile and stationary use

Plasma medical research – new pharmaceutical and medical fields of application (third-party funded project)

Based on the successful application-oriented research of the large interdisciplinary project Campus PlasmaMed funded 2008-2013 by Federal Ministry of Education and Research, the aim of this project was to investigate new ideas of potential use of cold atmospheric plasma in medicine and pharmacy and to estimate its application purposes.
Five main research goals and topics were followed:

1. Continuation of scientific support of ongoing clinical application tests of the cold atmospheric plasma jet kINPen MED by basic research on plasma effects on skin and wounds as well as by animal experiments on the one side and by plasma-diagnostic approaches to find a useful technique for on-site diagnostics of the plasma on the other; improvement of concepts of jet-based treatment of larger areas
2. Future development and optimization of plasma sources and technologies for application in dentistry with focus on treatment of peri-implantitis as well as treatment of dental implants before implantation
3. Development and laboratory testing of an endoscopic cold atmospheric plasma source for treatment of pulmonary tuberculosis
4. Basic research on and practical application of plasma-activated liquids
5. Plasma-based techniques in biotechnology

Top results of this project are:

- With an *ex vivo* study using skin biopsies it was demonstrated that after cold plasma treatment, the epidermal integrity and keratin expression pattern remained unchanged, i.e. no acute skin impairment was found. An induction of proliferating basal keratinocytes was detected after cold plasma exposure for 1 and 3 min, whereas an increase in apoptotic cells was found after 3 and 5 min of treatment. This means that at least under these experimental conditions *ex vivo* a clear difference between plasma treatment intensity to stimulate skin cell regeneration and plasma intensity to inactivate skin cells was found.
- In an animal study using an artificial ear wound model in mice, significant acceleration of wound healing by cold atmospheric plasma treatment was demonstrated with minor or no role of antiseptic plasma effect.

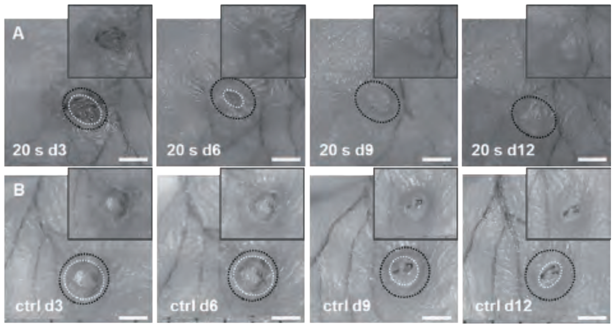

Fig. Artificial ear wound model in mice: Representative images of wound healing progress at several time points after wounding in the control (A) and treatment (B) group. Black circles represent wound margins and white lines indicate edges of wounds at indicated day after wounding. Inserts show wounds without lines in further magnification.

- Cell culture experiments covered by analysis of biopsies revealed that cold plasma is acting on a cellular level by modulating the redox-balance of the cells by influencing cellular metabolism and up-regulation of antioxidative mechanisms of radical defense and repair
- The concept of power measurement was realized successfully with the kINPen. Insufficient accuracy of measurement needs adaptation of a new procedure which was tested with dielectric barrier discharge plasma serving as comparison device yet.
- By actinometric investigations a maximum of electron energy distribution in the plasma was found. An implementation of this procedure for on-site plasma monitoring and control is possible but much more complex than power measurement.
- An arrangement of 8 parallel atmospheric-pressure plasma jets was technically realized functioning stable without mutual interferences.

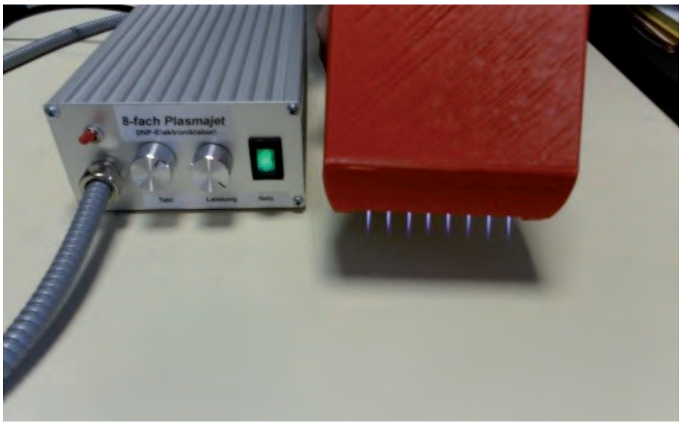

Fig. Laboratory prototype of a multi-jet with eight parallel plasma effluents

- By combination of mechanical cleaning (nylon brush or powder jet) and plasma treatment, inactivation and ablation of biofilm from dental implant material is possible which is the main precondition for successful peri-implantitis therapy. However, this procedure works very well using the atmospheric-pressure plasma jet kINPen08 but is less effective with the kINPen09. Because both laboratory models of the kINPen are not useful for patient application because of several technical and regulatory limitations, further optimization of this promising plasma-supported technology for peri-implantitis treatment is necessary.

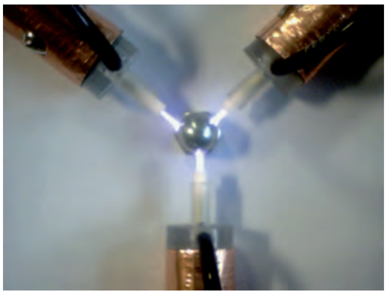
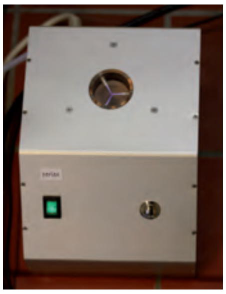

Fig. Action principle (left) and laboratory prototype (right) for pre-implantation plasma treatment of dental implants

- A technical concept and laboratory device for a plasma source for external pre-implantation treatment of dental implants was realized.

Fig. Laboratory prototype of a kINPen-based plasma device for intraoral application

- Based on the basic concept of kINPen MED, a technical concept and laboratory device for cold atmospheric pressure plasma fulfilling ergonomic requirements jet for intraoral application was presented and transferred to industry.
- A flexible plasma source for potential endoscopic application based on kINPen technology was designed and a laboratory device for in vitro experimental testing was realized. The general possibility to inactivate *Mycobacterium tuberculosis*, the most important pathogen of pulmonary tuberculosis was demonstrated.


Fig. Laboratory prototype of a flexible plasma source for potential endoscopic application based on kINPen-technology

- Basic research to improve the understanding of chemical processes in liquids following cold atmospheric plasma treatment was continued using an optimized laboratory test setup based on a surface dielectric barrier discharge that enables to treat up to 5 ml liquid volume.
- Both the relationship on nitrite to nitrate and the redox voltage were identified as important parameters for antibacterial activity of plasma-treated liquid.
- A laboratory prototype of a device for plasma activation larger liquid volumes up to 500 ml by plasma treatment was realized. With a 30 min treatment of 500 ml physiological saline a > 6 log inactivation of bacterial suspension was demonstrated.
- With the medicinal mushroom *Ganoderma lucidum* as first example, it was demonstrated that stimulation of growth as well as production of secondary metabolites of eucaryotic cells is generally possible. This opens up in principle the potential application of cold atmospheric plasma in the field of biotechnological production of active substances.
- These stimulation effects are dependent on the nature of the treated material (cell suspension vs. solid cultures) but also on the plasma treatment itself. Energy input is hypothesized to be a selection parameter.

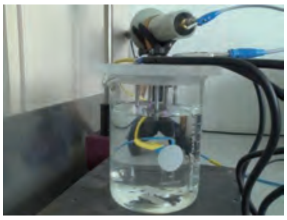
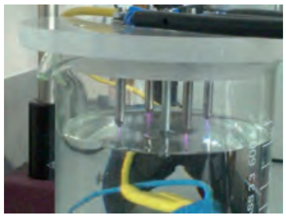

Fig. Experimental setup to for plasma activation of larger liquid volumes (max. 500 ml)

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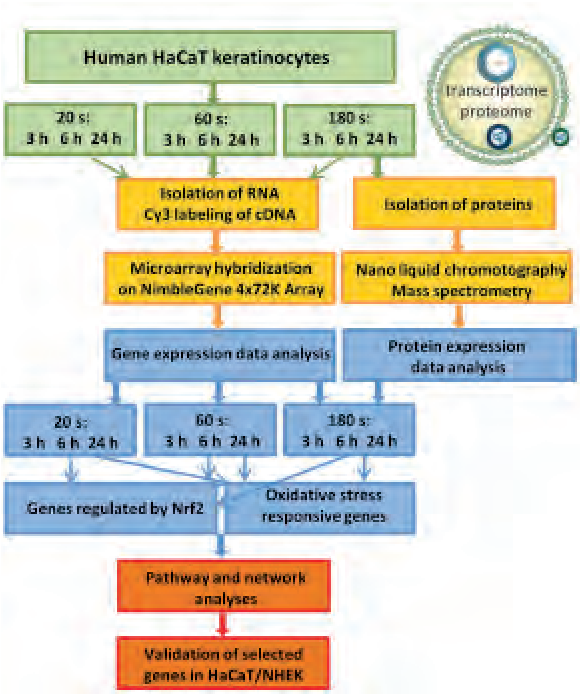
Plasmatis Centre for Innovation Competence – Cellular Effects (third-party funded project)

Problem

In 2009 the ZIK plasmatis started basic research in order to identify mechanisms and molecules involved in plasma mediated wound healing. During that time various standardizations of methods and inter-disciplinary research had been performed leading to the central result that a well harmonized cold physical plasma is able to stimulate cells. However, each cell type reacted differentially leading to different sensitivities towards plasma treatment. The identification of molecules involved in maintaining the redox-balance was one major open question.

Problem-solving approach



Functional annotation, pathway, network analysis, and graphical summary of NRF2 activation in keratinocytes after plasma treatment. The top gene interaction networks associated with plasma-treated HaCaT cells were predicted by IPA and are presented for all groups. About 30 genes are involved in the network. A solid line represents a direct interaction and a dashed line represents an indirect interaction between target genes (red, up-regulation; green, down-regulation). Plasma activates NRF2 signaling and induces an antioxidant response. Among others, HMOX1, FOS, JUN, JUNB/D, and BACH1 were regulated by plasma. Regulation of several components is simplified in the drawing. * Schmidt et al. 2015

Results

- Cell culture experiments covered by analysis of biopsies revealed that cold plasma is acting on a cellular level by modulating the redox-balance of the cells by influencing cellular metabolism and up-regulation of antioxidative mechanisms of radical defence and repair
- Combined analysis of plasma treated cells by applying transcriptomic and proteomic approaches revealed an activation of phase II antioxidative pathways

Technological benefits

Based on those results it is possible to have a first understanding of the mode of action of cold plasma treatment of human cells. Since each cell type reacts with a different sensitivity it is important to know which molecules are turned on and which signalling cascades are activated consequently.

Plans for 2016

Establishing the research group wound healing and thereby translating the cell culture results into a more patient sample driven analysis will help to gather more data on real life situation of how cells, tissues and even patients will react to a cold plasma treatment. For this next step collaborations with the University Medicine Greifswald as well as the Diabetes Competence Center at Klinikum Karlsburg – Herz- und Diabeteszentrum Mecklenburg-Vorpommern will be established.

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Plasmatis Centre for Innovation Competence – Extracellular Effects (third-party funded project)

Problem

Fundamental research in plasma medicine requires reproducible, defined and controllable plasmas interacting with biologically relevant liquids and with biological systems. In order to gain insight into fundamental plasma initiated mechanisms, the plasma composition needs to be tailored. For this, dominant pathways of reactive component generation need to be determined. In 2010 the ZIK plasmatis Group "Extracellular Effects" initiated this approach.

Problem-solving approach

Tailoring the plasma composition by the "Extracellular Effects Group" was achieved in three consecutive steps:

1. Establish state of the art diagnostics of the plasmas as well as of the treated liquids enabling a direct correlation of the results. This allowed an insight into the fundamental processes of plasma treatment of biologically relevant liquids.
2. Control the plasmas in a controlled way, in order to tailor the chemical composition by adjusting the composition of the reactive components in the liquid cell environment. The control of the reactive component composition was achieved by evaluating and applying the results of plasma diagnostics and numerical simulation. The aim was to be able to control reactive component groups separately.
3. Identify the processes for relevant wound healing from the results of the diagnostics of plasma and biologically relevant liquids in connection with the investigation of the treatment effects on the liquids to the cellular membrane. Combined with the results of the biological plasmatis group, biophysical models of the cell membrane in form of liposomes were used.

Results

- Main plasma initiated chemical pathways are identified (see Figure 1 left)
- Plasma can be tuned from pure reactive oxygen species dominated plasma to a reactive nitrogen species dominated plasma (see Figure 1 right)
- Plasma treatment can be tuned to e.g. kill bacteria and not harm human skin cells (with ZIK-ZE Group and Prof. Th. v. Woedtke Group)

Technological benefits

Based on those results it is possible to control at the same plasma parameters the composition of the resulting reactive species composition. Therefore it is now possible to identify relevant reactive component groups in e.g. cellular signalling processes. Furthermore, the approach poses a fundament for a controlled plasma medical treatment involving bacterial inactivation processes (ROS) and cell stimulating processes (RNS). A patent was applied for.

Plans for 2016

Establishing the research group plasma sources concepts, identifying further possible means to tailor plasma generated reactive species compositions. The approach is to use fundamental physics mechanisms to tune the resulting reactive species output.

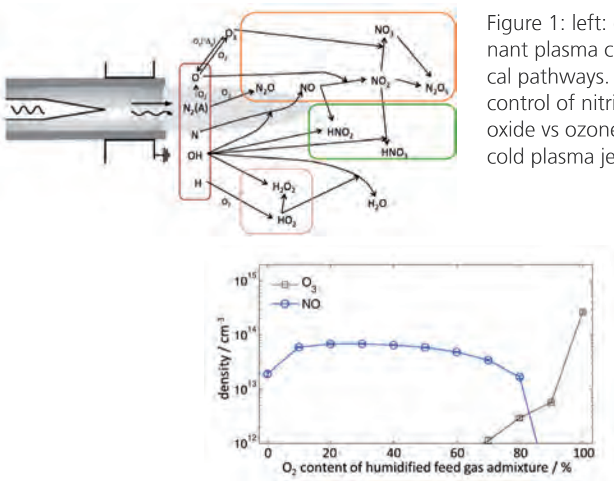

Figure 1: left: dominant plasma chemical pathways. right: control of nitric oxide vs ozone in a cold plasma jet.[1]

[1]These studies were awarded a research award (A. Schmidt-Bleker et al.) at the XXII Escampig in Greifswald

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PlasmaWundTex – Development of a novel wound treatment system on the basis of plasma technologies and the use of large-scale textile plasma sources for mobile and stationary use (third-party funded project)

The aim of the „PlasmaWundTex"-project was to develop a plasma source for the support of wound healing of large areas. The project was funded by the Federal Ministry for Economic Affairs and Energy under the ZIM framework (July 2013 – September 2015). Partner in this project have been DKI GmbH (development of electronic components) and ITP GmbH (development of the textile basis). In addition to Jet-based plasma sources which are already used in medicine, this plasma source should be a DBD based source, should act as a "plaster", should treat larger areas, and should be made on the basis of textile materials. The following requirements have been agreed between the partners in order to develop a prototype ready to be transferred to a product:

1. The operation of the device shall be as easy as possible without the need to give special advice or special training to the operator. It was aimed to have a device with a so called "one-button-operation" so that the operator does not necessarily be health personnel.
2. The applicator of the device shall treat larger areas directly and uniformly.
3. The applicator shall work together with conventional dressing material and shall be in-line with usual therapy options.
4. The entire device shall be portable, ideally with less than 5 kg weight.
5. The applicator shall be disposable to avoid additionally steps for sterilization/disinfection.

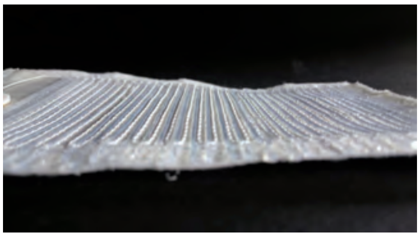


Fig 1: Side view of the plasma source showing the design of the electrodes.

Fig 2: A „spool" of the plasma source indicating the possibility of a roll-to-roll production.

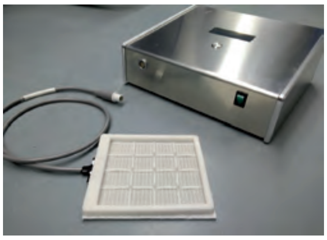
Results

During the project we developed an applicator which is able to treat areas of about 100 cm² with a DBD plasma. Compared to a jet-plasma this value is about 100 times higher without moving the plasma source. To investigate the effectivity of the plasma treatment we performed microbiological experiments on the basis of DIN SPEC 91315 (this is also a result of an INP project!). We have found out that even for short times of less than 1 minute the treatment of the plasma applicator of an area of 100 cm² is effective.

The selection of materials and the design of the arrangement of the components of the plasma source were made in a way that a cost-efficient roll-to-roll production is possible. The entire device and its components are designed to be in-line with the regulations for the certification as medical device. This includes particularly the electrical connection of the applicator to the control unit.

The operation of the "Plasma plaster" takes place without any additional special dressing material. For example, the plasma treatment could take place during the regular change of the usual dressing material. As agreed and required by the partner, the applicator and its electrical connection is designed as a disposable, there is no need for sterilization / disinfection after usage. The control unit is made on the "one-button-principle" including several safety mechanisms to avoid injuries of the patient and the operator. The control unit is portable due to its weight of less than 4 kg.

Finally, we have realized a prototype of a plasma plaster on the basis of textile materials with integrated safety features of the entire device. The certification as a medical product will be the task of neoplas tools GmbH and its partner. But before this, several steps of product design are needed in order to follow advices of medical professionals. The INP is again on a good way to have another successful example of the institute's motto: From Idea to Prototype!



Project team: Jan-Simon Baudler, Philip Turski, Stefan Horn, H. Sawade, Klaus-Dieter Weltmann

Fig 3: First prototype of the plasma plaster device including the control unit. The white frame attached to the plaster serves as a spacer between the plasma and the patient's skin.

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Introduction

In spring 2015 the new Research Program Decontamination was formed from its predecessors the Research Programmes Bioelectrics and Pollutant Degradation and in addition integrating efforts in decontamination that have been part of the Research Programme Plasmamedicine. The new structure is now combining research and development that is conducted at the INP Greifswald for the decontamination against biological and chemical pollutants that are found in air and exhaust gas streams, in drinking and wastewaters, on fresh produce and food packaging and on surfaces in general.

For all these target areas especially non-thermal plasmas that are generated at atmospheric pressure in air and preferably with air offer a novel and promising approach finding solutions for respective global and societal challenges. Non-thermal plasmas demonstrate to be a solution to uphold contamination levels that are mandated with respect to the release of pollutants into the environment by increasingly strict regulations. Depending on the respective objective (air, water, food, surfaces) different approaches are pursued that are exploiting the unique advantages of non-thermal plasmas:

- Generation of chemically reactive species, uv-radiation, electric fields and shockwaves on-demand and on-site.
- Process control, including switch-on/switch-off as needed, depending on treatment needs.
- Generally, no additional toxic chemicals are needed.
- In many cases no harmful residuals are observed that would require post-treatment steps.

A particular strength of non-thermal plasma methods for decontamination are the generation of reactive nitrogen and oxygen species, such as NO and OH radicals. These medium or short-lived species are known for their high oxidation potential that allows them to decompose even stable chemical compounds, such as volatile organic compounds and pharmaceutical residues but are also highly effective against harmful microorganisms. Since so far no resistance of bacteria against plasma exposures has been observed, plasma methods might present a promising solution also for the elimination of resistant bacteria in health care environments. To develop the potential of plasma methods towards applications a thorough understanding of both the underlying mechanisms responsible for the generation of reactive agents as well as the careful investigation on the interaction with microorganisms and chemical reaction with pollutant is necessary. Accordingly the tasks of the Research Programme Decontamination include:

- Development and characterization of new plasma sources.
- Analysis of plasma-chemical processes.
- Investigation of biophysical and biochemical interaction mechanisms.

Based on this knowledge new processes are being developed for different respective applications.

Application Potential

The potential of the effects of non-thermal plasmas on microorganisms and chemical compounds is primarily the controlled and to a certain degree tailored degradation and elimination. In addition reaction chemistries can be exploited for the targeted conversion of chemicals or the extraction of valuable substances from cells.

- Biological and chemical decontamination of pollutants, including pharmaceutical residues, in drinking water, waste waters and process water.
- Biological and chemical decontamination of pollutants, including volatile organic compounds, in air and exhaust gas streams.
- Microbial decontamination of food, including meat products and fresh produce.
- Microbial decontamination of surfaces, including food packaging, pharmaceutical containers, medical devices and textiles.

In many cases non-thermal plasmas can offer a stand-alone solution with customized plasma generators and plasma processes. Effectiveness and success of the method depend on application needs, especially contamination levels and required throughputs. An additional advantage of plasma treatments is the possibility to combine them with other established methods for decontamination and this way enhance the overall efficacies and efficiencies of the overall process. Supplemental or existing methods can for example include catalytic converters, or filter and absorbers. Based on electrical means, atmospheric pressure plasma processes can hereby usually be included in existing production and treatment chains with moderate effort.

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Fundamentals of discharge generation with short high voltage pulses (core-funded project)

Problem

During the last couple of years the generation of atmospheric pressure plasmas with short high voltage pulses has emerged as a more efficient way for different applications. This is including the conversion of noxious gases in air treated with corona reactors, the removal of volatile organic compounds in air by dielectric barrier discharges or the decomposition of pharmaceutical residues in water by submerged discharges. How the pulse parameters (rise time, duration, amplitude, polarity etc.) affect the pursued decontamination objectives by improving for example plasma chemical processes is a major challenge in understanding. Short and transient mechanisms, often in the nanosecond range, have to be investigated and put into relation with chemical reactions that develop on much longer time scales. Accordingly many of the diagnostic and analytical efforts of the Research Programme Decontamination are dedicated to understand the underlying mechanisms for the different plasma sources and methods that are investigated.

Problem-solving approach

Assisted by the Department Plasma Source, the Research Programme has built up the expertise for the application and diagnostic of high voltage pulses in the nanosecond to microsecond range. For the very short pulses dedicated pulse generators were installed and cooperations with research groups that are experts in the field, in particular the University of Technology at Eindhoven, Netherlands, and the West Pomeranian University of Technology at Szczecin, Poland, have been established. Mutual visits have been funded by the PlasmaShape project. Expertise in pulsed power is combined with the plasma diagnostic expertise at the INP to describe discharge development spatially and temporally resolved. Especially fast imaging and spectroscopic techniques are applied. Experimental studies are complemented by hydrodynamic modelling and chemical analysis. Funded by PlasmaShape have been researcher positions (postdocs) with the objective for an in-depth study of reaction chemistries.

Technological benefits

A detailed understanding of the mechanisms responsible for the plasma generation with respect to reaction chemistries and other active agents (e.g. electric fields, shockwaves, uv-emissions) immediately correspond to a better control of these processes. Accordingly technological benefits are:

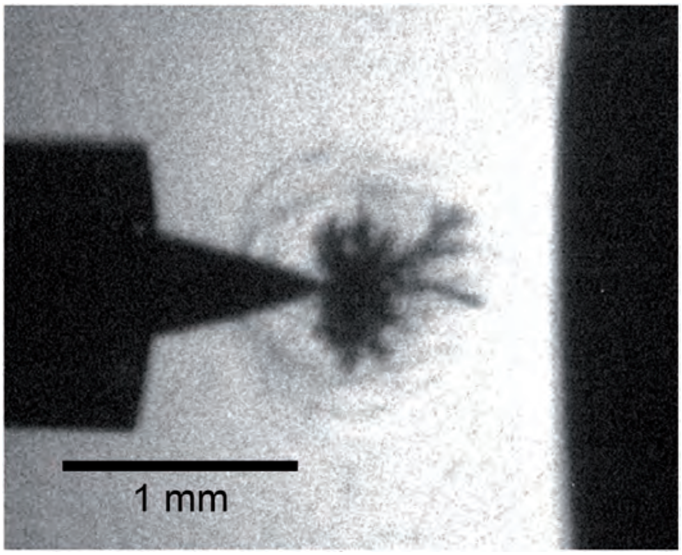
- Optimization of plasma processes for pollutant degradation and microbial decontamination based on plasma parameters and discharge operating parameters.
- Increasing energy efficiencies of plasma processes with respect to operating parameters.
- Emerging novel application by utilizing synergistic effects with non-plasma methods.

Results in 2014/15

The influence of pulse parameters has been studied in detail especially for the electrical breakdown on barrier discharges and for the pulsed breakdown and plasma generation directly in liquids. For the operation of dielectric barrier discharges we could show that a steeper voltage slope (75 V/ns instead of 200 V/ns) leads to a higher transferred charge and electrical energy per cycle. Further breakdown characteristics are changing significantly for pulse widths that are on the order of the ion translation time (~1 µs). For the instigation of corona discharges generated directly in water we found that for pulse durations of 100 ns the hydrogen peroxide production rates are increased by about a factor of four when compared to pulses in the microsecond range. The result indicates that initially also hydroxyl production rates are enhanced by the generation of the plasma with shorter pulses. Most interesting is the plasma generation in liquids for high voltage pulses of 10 ns that are much shorter than the actual discharge development of several microseconds. In this case different discharge phases that are observed for longer pulses have been observed. With this type of plasma mechanisms can be exploited which presumably allow for much higher bacterial inactivation rates but also favour reaction mechanisms that allow specific high quality material modifications and synthesis, such as for example the generation of nanoparticles.

Plans for 2016

The improved understanding of atmospheric pressure plasmas instigated with short high voltage pulses is currently transferred in the design of more efficient plasma treatment methods for decontamination. In addition new possibilities that have shown up from the fundamental studies of very short pulses will further be investigated together with the Research Programme Surfaces and Materials with the goal to explore their economic potential. Another emerging topic, especially for the Research Programme Decontamination, is the generation and sustainability of plasmas in multiphase media, such as water vapours. This field is gaining increasing attention around the world and will be studied in more detail at the INP. Herby a strong collaboration with the Research Programme Plasmamedicine with respect to plasma-liquid interactions is expected.



Discharge development of a corona discharge generated in water with a unipolar, rectangular high voltage pulses of 10 ns duration and 50 kV amplitude.

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Innovative Monitoring- and Decontamination Processes for Microbial Safety in the Production Chain of Fresh Produce Food – safe-fresh, subproject: Plasma Processes for Generation of Hygienic Safety (BMBF // third party funded project)

Problem

Convenient food, especially fresh-cut produce, can causes severe health problems. The FDA listed leavy greens on the first rank of the ten riskiest food products. The German consumer magazine "Stiftung Warentest" conclude that fresh-cut salad should be treated with the same caution as minced meat.

The problem arises in most cases from early contamination during the growth of the plants. Standard procedures which are applied during the processing of the food e.g. washing are not capable to reduce the microbial load completely. Thus, after cutting packaging the residual microorganisms find optimal growth condition as soon as the temperature is raised.

Problem-solving approach

In order to overcome this problem the complete production chain has to be evaluated. The fast monitoring of the microbial load is essential for an effective and gentle decontamination process. Different decontamination processes are investigated at different production steps to analyze in which stage which treatment offers the best results.

In the subproject of the INP plasma based processes for sanitation are in the main focus. Two different processes are examined:

1. Dry treatment (PPA = plasma processed air): bases on the plasma source PLexc, a RNS containing process gas is produced, which has antimicrobial properties.
2. Wet treatment (PPW = plasma processed water): the interaction between water and PPA leads to water with antimicrobial properties.

Technological benefits

The project validates the industrial potential for the PPA as well as the PPW technology and shows the possibilities for a scale up to pilot plant dimensions.

Results in 2014/15

Both processes are extensively applied on salad and spouts as shown in Fig. 1 for the PPW process on iceberg lettuce. The results depend on the type of specimen and microorganism. It is shown in summary that inactivation of more than 2 log10 steps is possible in any combination.

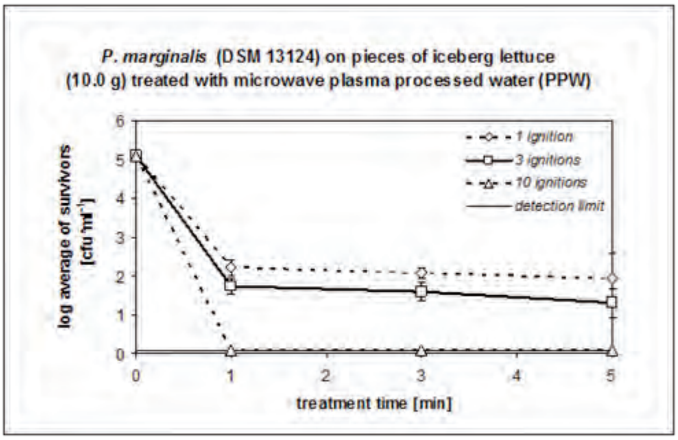

Figure 1: Treatment of iceberg lettuce with plasma processed water. The number of ignition indicates the interaction time between water and PPA, details in Schnabel et al. 2015.

Figure 3: Technical center of Jürgen Löhrke GmbH, Lübeck. Installation of the pilot plant with two INP plasma devices.

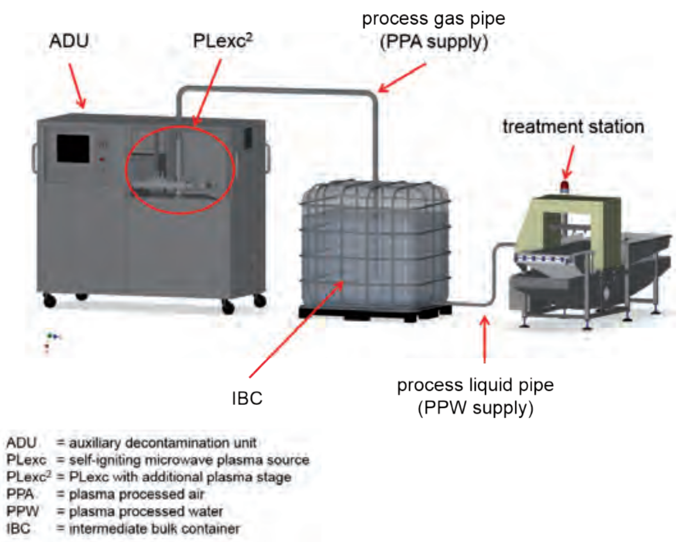

Figure 2: Scheme of the PPW process as realized in the pilot plant salad washing at Jürgen Löhrke GmbH, Lübeck.

The processes are scaled up to pilot plant dimensions as shown in Fig. 2 and 3.

The decontamination results are comparable with the lab scale experiments and therefore on a first trial competitive to classical methods.

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Funded by:
German Federal Ministry of Education (BMBF)
Contract no. 13N12428

Decontamination of eggshell by means of atmospheric plasma (BMWi // third party funded project)

Problem

Infections caused by Salmonella are worldwide one of the most important zoonoses. In Germany Salmonellosis is on rank two of the bacterial induced infection diseases. The main risk arises from raw or minimal processed food produce of animal origin. The application of disinfection methods is strongly restricted by legal regulations.

Problem-solving approach

In order to overcome this problem three different plasma methods are applied in the project. One is a direct treatment with a plasma jet, second is a semi-direct method using a surface dielectric barrier discharge and third is an indirect treatment method using plasma processed air.

Technological benefits

The project validates the industrial potential for three different plasma technologies.

Results in 2014/15

A result of the project is the development of the Flexible Electrode Plasma Source (FEPS; Figure 1 and 2), which is capable to treat a complete egg at once.

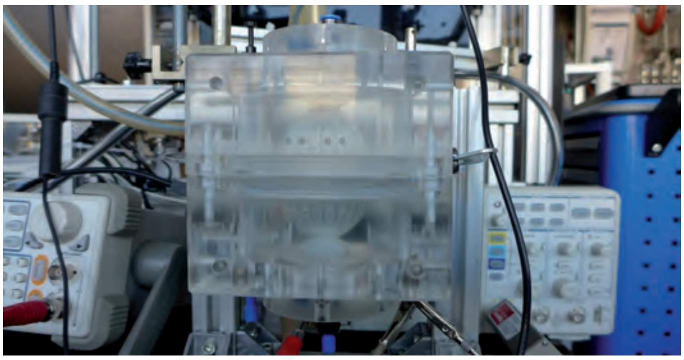

Figure 1 Flexible Electrode Plasma Source (FEPS)

Due to the very low margins in egg production the operation cost of the plasma source have to be as low as possible. Therefore, a plasma source based on a surface dielectric barrier discharge with flexible electrodes was adapted to the egg shape in order to minimize gas consumption and to reduce the needed high voltage.

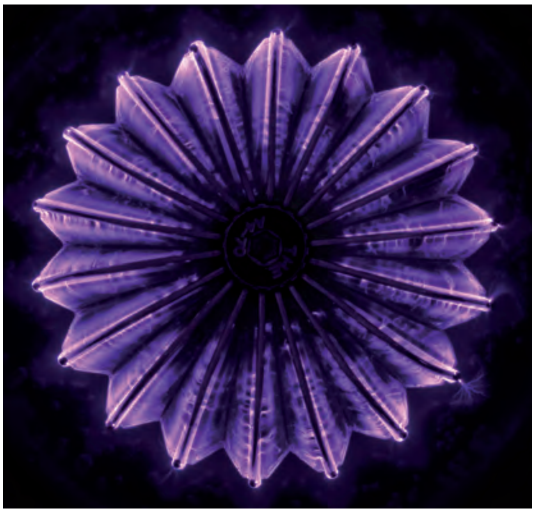

Figure 2 Picture of the operating FEPS

A special focus was set on the operation with ambient or compressed air as shown in Fig. 3.

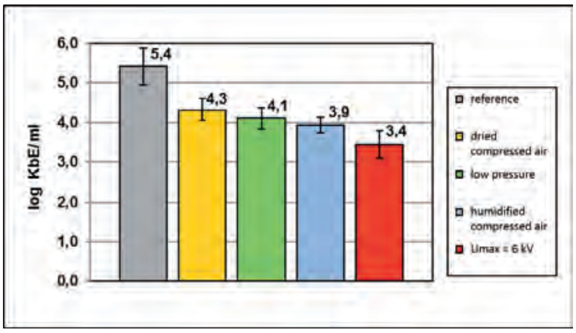

Figure 3 Comparison of different parameters on the decontamination efficiency of FEPS

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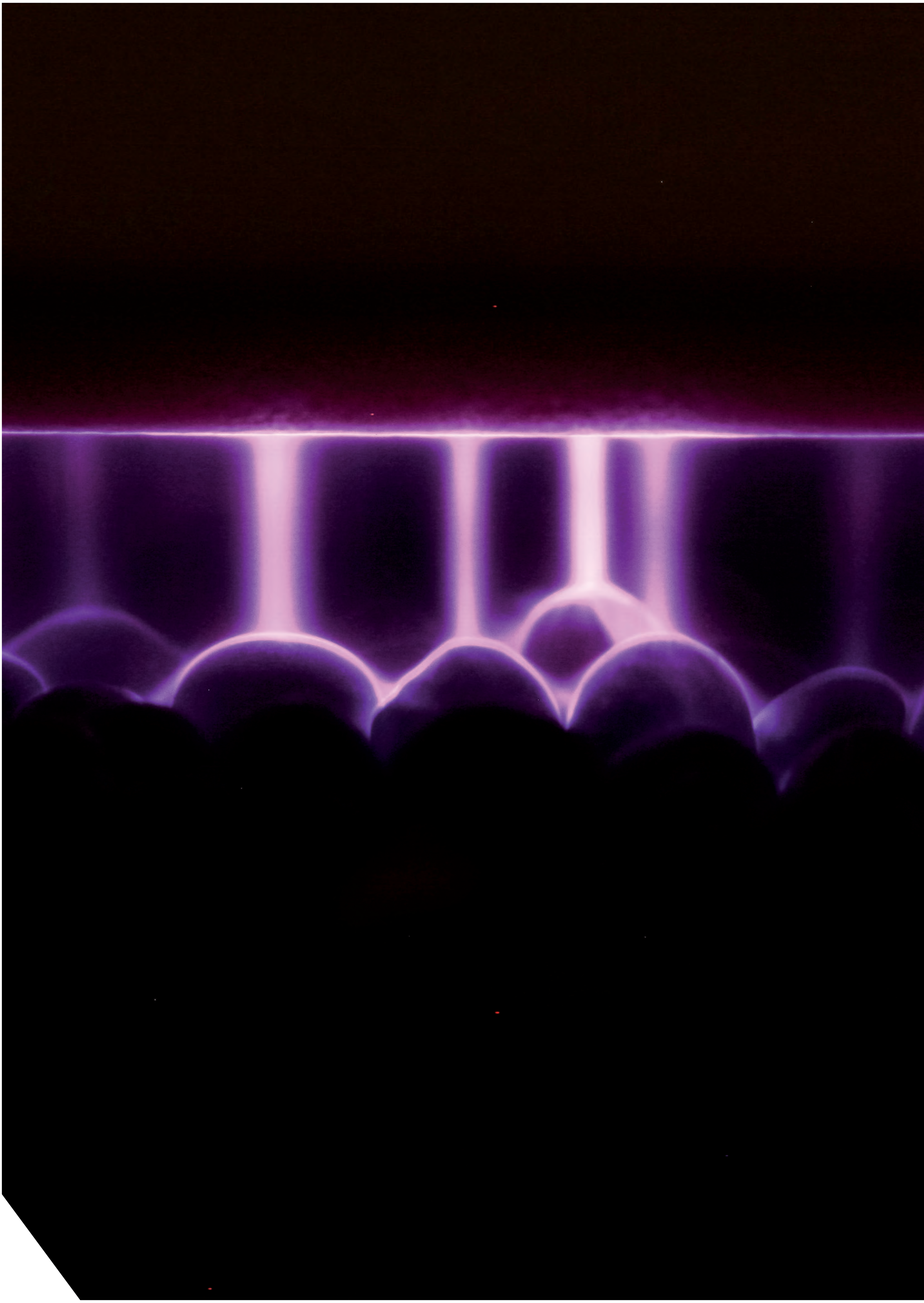
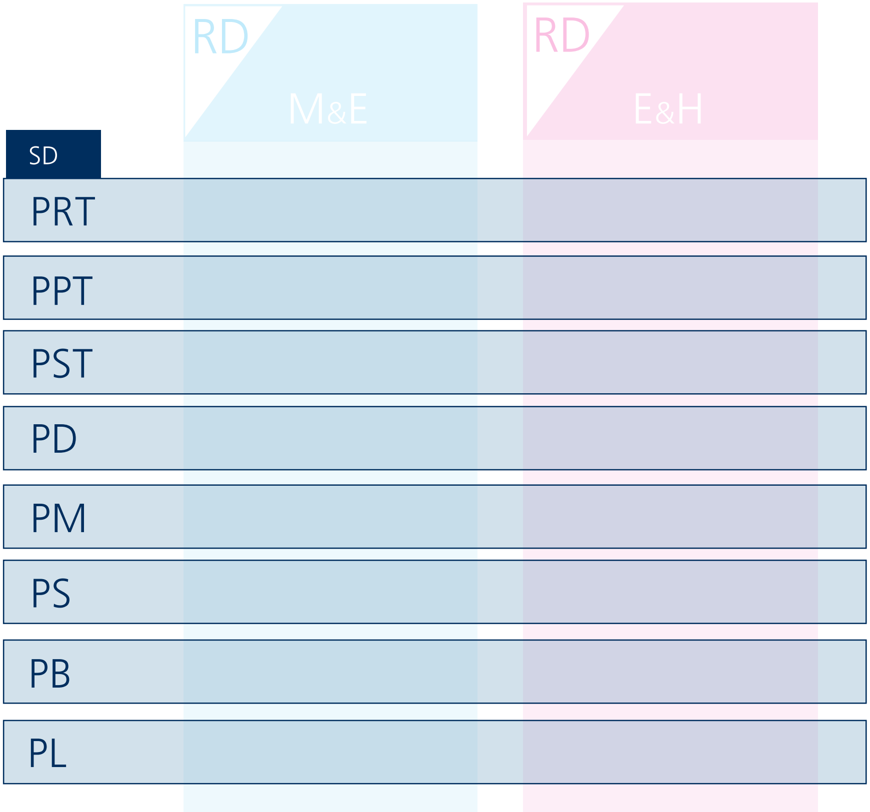




Matrix structure of the Research Divisions (RD) and Scientific Departments (SD)

Research Divisions Plasmas for Materials & Energy (RD M&E)

- Research Programme Surfaces and Materials
- Research Programme Process Monitoring
- Research Programme Welding and Switching

Research Divisions Plasmas for Environment & Health (RD E&H)

- Research Programme Bioactive Surfaces
- Research Programme Plasma Medicine
- Research Programme Decontamination

Scientific Departments (SD)

- Plasma Radiation Techniques (PRT)
- Plasma Process Technology (PPT)
- Plasma Surface Technology (PST)
- Plasma Diagnostics (PD)
- Plasma Modelling (PM)
- Plasma Sources (PS)
- Plasma Bioengineering (PB)
- Plasma Life Science (PL)

Scientific Department for Plasma Radiation Techniques

Key aspects

The Department's work focusses on the experimental analysis of:

- Free-burning and wall-stabilized arcs
- Vacuum arc discharges
- Dielectric barrier discharges
- Ultraviolet (UV) and vacuum ultraviolet (VUV) plasma radiation sources

Work objectives

- Plasmas in electrical engineering, particularly arcs in gas-insulated and vacuum switchgears
- Arcs in joining technology, particularly arc welding, plasma welding and plasma hybrid welding
- Filamentary plasmas in plasma-chemical applications, e.g. environmental technology
- UV/VUV plasma radiation sources in particular for biological applications

Work equipment

- High current laboratory for the analysis of arc plasmas in the kA range with different frequencies
- Setups with welding power sources for the study of welding processes
- Specific diagnostics for arc plasmas and their electrodes, particularly optical emission spectroscopy including adapted methods for the determination of species densities and plasma temperature
- High-speed image recording for the dynamic analysis of arcs including ignition and material conversion
- Diagnostics for the time-resolved analysis of non-thermal, filamentary atmospheric pressure plasmas
- Thermography and pyrometry for the determination of surface temperatures
- X-ray diagnostics, including tomography
- Electrical metrology and methods for time series analysis
- Radiometry and photometry diagnostics of light sources
- Diagnostics for UV/VUV sources, particularly for the absolute measurement of UV/VUV radiance

Medium-term focuses

The optical diagnostics of arcs and atmospheric pressure plasmas is a focal point over the medium term. The laboratory for high current pulses and experimental investigations of switching arcs will be extended together with the further establishment of expertise in electrical engineering.
Methods of optical emission spectroscopy will be improved and completed by different methods of absorption spectroscopy for the study of plasma regions of low self-emission. The methods will be improved in the directions:

- higher sensitivity and spatial resolution to study plasma regions near surfaces in more detail
- robustness against distortions in real applications
- mobile and flexible use
- quantitative characterisation of plasma structures with high dynamics and without spatial symmetry.

The methodical developments will also result in concepts for non-invasive methods for online processes control.

Technological benefits

The diagnostic of electrical arcs and vacuum discharges serve, among other, for model improvement and validation of the simulation of switchgear. Here, simulations contribute significantly to a reduction in development times. The studies of free-burning arcs will result e.g. in concepts for an increase of process safety and of the application range of arc welding processes. The analysis of non-thermal atmospheric pressure plasmas has supported the development of new application concepts and sources for plasma-chemical substance conversion and surface modification.

Scientific Department for Plasma Process Technology

Key aspects

- Modification of nano- or molecular structured catalytically active surfaces for components of renewable energy sources
- photosensitization of semiconductor surfaces for regenerative hydrogen production
- catalysts for fuel cells, electrolysers, photo electrochemical cells
- surface characterization

Work objectives

- development of plasma-assisted processes for catalytically active surfaces
  - combination of PVD and PECVD
  - co sputtering
  - reactive sputtering
- development of surfaces with special properties
  - Photo- and electro-catalytically active surfaces
  - High porous nanocomposite films
  - Corrosion resistance coatings
  - Large surface area
  - Electrically conductive or semiconductive properties
  - Chemical, electro chemical and photo chemical characteristics
- Expertise in characterization of electrochemical, optical, morphological and structural properties

Work equipment

- Low pressure pressure plasmas and magnetron sputter sources
- Devices with up to three plasma sources for combined depositions
- Plasma diagnostics, energy inflow measurements
- Diagnostics of surfaces with atomic fource microscope, Brunauer-Emmet-Teller method, contact angle measurement devices, Xray Diffraction, Reflectometry, UV/Vis, FTIR, RAMAN, digital optic microscopy
- Photo and electrochemical characterization methods
- Particle size measurements

Medium-term focuses

- Development of photoactive catalyst surfaces and electrode catalysts for solar water splitting
- Development composite films with different material combinations, metal/polymer, metal/metal oxide, metal/graphene
- Development of electrodes for electro chemical sensors
- Synthesis of new dielectric materials for capacitors
- Development of adsorbents for gas scrubbing

Contribution of the INP to technological development

The plasma based synthesis of new materials offers great potential in applications of actual social relevance, in particular for the hydrogen technology, photovoltaics and material recycling. It provides new opportunities processing of catalytically active materials especially in energy conversion technologies in which planar geometries dominate. The study of plasma processes for the production of e.g. nanocomposite films and for surface modification supports the development of reliable and economically justifiable mass production methods.

Scientific Department for Plasma Surface Technology

Key aspects

- Plasma based activation, functionalization, coating, etching and implantation of surfaces
- Refinement of plastics, metals, glasses, biomaterials and composites for applications in High-Tech and Life Science
- Analysis and control of plasma enhanced processes for surface modification
- Modified surfaces for controlling the interaction with biological systems

Work objectives

- Development of processes for plasma based surface modification in small and large scale
- Plasma and ion-assisted processes for the development of functional coatings on plastics, glasses, metals, bio-materials and composites with planar as well as 3D geometry
- Investigations on deposition of organic, inorganic and metal based coatings by atmospheric pressure plasma processes (e.g. plasma jet, dielectric barrier discharge)
- Plasma based processes for adjusting interface properties (e.g. by plasma based ion implantation)
- Investigations on surface polishing by plasma enhanced processes
- Process development by new plasma diagnostic methods and modelling/simulation

Work equipment

- Several atmospheric pressure plasma process systems, like dielectric barrier discharge device, plasma jets, plasma spraying device, plasma polishing system for basic research and industry-oriented running
- Several low pressure plasma process systems (microwave, RF (inductively or capacitively coupled), DC, DC pulsed) for basic research and industry-oriented running of Plasma Enhanced Chemical Vapour Deposition (PECVD), Physical Vapour Deposition (PVD, HiPIMS), Plasma Immersion Ion Implantation (PIII) and Plasma Ion Assisted Deposition (PIAD)
- A multi-reactor system with simultaneous access for plasma and process diagnostic processes
- Process monitoring by plasma diagnostics, e.g. spectroscopy, mass spectrometry and probes (Langmuir, multipole resonance)
- Surface and film analytics for the determination of chemical structure, topology, morphology, optical properties, scratch resistance, hardness and release property: among other, highly resolved scanning X-ray Photoelectron Spectroscopy (XPS), in-situ XPS, infrared Attenuated Total Reflectance (ATR) microscopy, atomic force microscopy (ATM), scanning tunnel microscope (STM), scanning electron microscopy (SEM) with Energy Dispersive X-ray (EDX) and 3D visualization, digital optic microscopy, ellipsometry, spectral photometry, profilometry, contact angle measurement and atomic absorption spectroscopy (AAS)

Medium-term focuses

The focus of work will be on the investigation and development of plasmas processes for optics, surface polishing, tool coatings and applications in modern building trade. Furthermore, plasma-chemical surface functionalization as well as plasma-chemical and plasma-physical coating deposition will be examined for applications in biomedical technology. The Department is increasingly emphasizing normal pressure plasma processes for surface treatment. All the results will be used in industry-relevant projects.

Technological benefits

Functional surfaces and films are the basis of many high-tech industries such as tools, automotive, aerospace, packaging, optics, semiconductors, biomedical engineering or microsystems. The subjects offer a huge potential to modify surfaces and produce functional films under atmospheric pressure so that applications such as passivation film systems for complex (3D) components (e.g. sensors), corrosion protection, barrier layers, selective release of active substances, control of wettability and antimicrobial effective surfaces are possible, locally and for difficult-toreach geometries (such as edges, cavities). The plasma based cleaning, deburring and polishing of metallic materials are of high interest in several applications concerning corrosion resistance, decoration, electric conductivity, high efficient production and cleaning processes as well as health.

The process control based on the knowledge of plasma parameters results in new quality for the production process with regard to reproducibility, homogeneity, and an improvement in the energy efficiency.

Scientific Department for Plasma Diagnostics

Key aspects

- Application of diagnostic methods such as optical spectroscopy, including laser based techniques, complemented by probe measurements and extracting techniques such as mass spectroscopy, for basic research as well as for studies under industrial conditions
- Focus on scientific and applied subjects relevant for the areas of materials, energy and surfaces
- Networking of the INP competencies
- Optimizing and further development of plasma diagnostic methods

Work objectives

- Analysis of plasma chemical substance conversion in the gas phase
- Study of the kinetics of transient molecules
- Investigation of specific plasma components and their effect on surfaces
- Optimization of plasma chemical industrial processes
- Investigation of mechanisms relevant for heterogeneous, plasma-assisted catalysis and its influence on processes of substance conversion
- In-situ monitoring of the properties of charge carriers in plasmas
- Development of technologies for ultra-sensitive optical trace gas detection

Work equipment

- Various ultra-sensitive laser spectroscopy techniques based on lasers in a spectral range from 3 to 20 µm, as well as related detection technologies, e.g. infrared diode laser absorption spectroscopy
- Probe diagnostics, mass spectrometry and optical emission spectroscopy
- Process monitoring of various types of diagnostically accessible direct current , radio frequency and microwave plasmas
- Industry-related plasma reactors working in continuous wave or pulsed operation appropriate for specific diagnostic tasks

Medium-term focuses

- Linking of plasma-chemical basic research with plasma technology
- Control of industrial plasma reactors by the use of spectroscopic methods
- Development of innovative diagnostics to study the kinetics of transient molecules in plasmas and in interaction with surfaces
- Development of new state-of-the art diagnostics for ultrasensitive trace gas detection
- Analysis of the role of plasma-stimulated solid surfaces

Technological benefits

The application of modern methods of plasma diagnostics is the key for the understanding of complex plasmas. Molecular plasmas containing a variety of different species are characterized by a number of interesting and useful properties. Their wide spread technological applications range from resource-protecting surface treatment, for example, in the semiconductor industry, to disinfection, sterilization, exhaust gas removal, gas scrubbing, particle degradation and the treatment of water, air and special waste.

Scientific Department for Plasma Modelling

Key aspects

- Self-consistent modelling of low-temperature plasmas
- Multi-fluid description and flow simulation
- Modelling of jet and arc plasmas
- Plasma chemistry and radiation transport
- Kinetic description of charge carriers in non-thermal plasmas
- Interaction of plasmas with walls and surfaces

Work objectives

The Department for Plasma Modelling deals with the theoretical description and analysis of low-temperature plasmas with technological and scientific relevance, where the main focus is non-thermal plasmas. The adequate numerical modelling of these plasma requires the

- development of an appropriate plasma model,
- formulation of hydrodynamic and kinetic equations, respectively, for the species of the plasma and their coupling with equations for the electric and magnetic field,
- search and evaluation of atomic data,
- development of appropriate numerical methods for the resulting set of differential equations or the usage of commercial software packages,
- solution for selected parameter ranges as well as
- visualization and interpretation of the results.

The complexity of the complete description necessitates that partial problems such as the kinetic description of charge carriers, the plasma-chemical reactions, the treatment of radiation transport and the analysis of spectra are treated separately.

Work equipment

The description and analysis of weakly ionized plasmas takes place by means of both numerical methods developed at INP and commercial software packages. The problem-specific methods of INP are characterized by high efficiency, stability and accuracy. The model calculations are executed on modern clusters whose availability has made the theoretical description of the complex, multi-dimensional problems possible in the first place. The studies are usually performed in close connection with experimental studies and funded projects at INP as well as in cooperation with national and international partners from research institutions and industry.

Medium-term focuses

The medium-term focus of the Department of Plasma Modelling is on the realistic description and analysis of the properties and the behaviour of scientifically and technologically relevant low-temperature plasmas such as plasmas for the processing and coating of surfaces, for pollutant degradation, in switching devices and for cutting and welding. The investigations allow for a deeper physical understanding and the quantitative determination of the

- temporal and spatial variation of the densities of individual plasma components,
- power input and dissipation of energy due to collisions and radiative processes,
- particle and energy transport in the plasma,
- electric and magnetic fields occurring in the plasma, and
- interaction of individual species with walls and surfaces.

Technological benefits

The research of the mechanisms and processes provides significant contributions to the physical understanding of the complex behaviour of low-temperature plasmas in experimental arrangements and technological applications. Based on extensive parameter studies, model calculations make a systematic optimization of technological plasmas possible, for instance with respect to the electric power input of process plasmas and the plasma-chemical process control for surface modification and pollutant degradation. Predictive models of arc plasmas support the optimization of the design and operating conditions of plasma torches in joining technology and for surface treatment. The analysis of microdischarges in dielectric barrier discharges aims at the generation of stable and well-defined atmospheric-pressure plasmas for industrial applications. The modelling of plasma jets at atmospheric pressure contributes e.g. to the improvement of the uniformity and composition of the deposited thin films.

Scientific Department for Plasma Sources

Key aspects

Development and characterization of non-thermal atmospheric pressure plasma devices for the treatment of surfaces, wounds, sensitive goods, air/off-gases and liquids, e.g. Dielectric Barrier Discharges (DBDs), Corona Discharges, Transient sparks, and, Plasma jets

Work objectives

The Scientific Department's task is to support all research programs at INP in the development and diagnostics of atmospheric pressure plasma sources of different kinds, in particular for biomedical applications, treatment of contaminated surfaces, treatment of contaminated gases, treatment of polluted water and other liquids. The staff in the department deals with the construction of plasma service and also provides the support of usage at internal and external partners. The construction already takes into account aspects of safety and later possible certification. Within the last years the generation of plasma in liquids and the necessary construction of pulsed power devices was successfully incorporated.

The additional focus is the fundamental characterization of the plasmas under operation by means of electrical studies, optical emission spectroscopy, temperature analysis and chemical analysis. Within this context it is aimed to determine the power balance as well as to estimate the dosage of the plasma treatment. In particular cases (e.g. treatment of media in larger volumes) the similarity and scalability is investigated. Therefore it is aimed to understand the physical mechanisms of the breakdown as well as the plasma chemistry. The impact of plasma treatments on cells, biological tissues (e.g. skin) and organisms is evaluated in cooperation with Departments Bioegineering and Plasma-Life Science.

Work equipment

Development laboratories for atmospheric pressure plasma sources including high voltage power supplies (pulsed power) and thermal and spectroscopic characterization. A portfolio of plasma sources with different parameters and peculiarities is available. The departments holds special diagnostics for the investigation plasma dynamics and emission, in particular time-correlated single photon counting.

Application laboratories for "Pollutant degradation in gases", "Water treatment" and "Electrode development" including analysis of plasma chemical reactions e.g. Fourier Transform Infrared spectroscopy, Flame Ionisation Detection and Gas or Liquid Chromatography. The department is also able to perform field tests on industrial facilities.

Medium-term focuses

The department will continue to develop, construct and characterize specific plasma sources on demand as desired from the institute and the industry. Besides plasma medicine and environmental applications the decontamination of surfaces and goods for antimicrobial safety and hygiene will be considered in the next years. The consolidation of the actual portfolio of demonstrators and prototypes is on the way. Aspects of flow dynamics, pulsed power coupling and plasma chemical similarity for up-scaling issues will be more focused.

Scientifically the role of plasma-surface interaction will be in the focus. The role of the material (e.g. dielectrics in DBDs) on the breakdown is investigated in cooperation with department plasma radiation and plasma simulation. Furthermore, the synergy of plasmas with adsorbing agents or catalytic surfaces will support the development of new applications in plasma chemistry and life-science, as a higher efficiency and selectivity can be realized with such approaches.

Technological benefits

The availability of safe, reliable and efficient atmospheric pressure plasmas sources is the precondition for the successful transfer of research into application in many fields, in particular life—science and medicine, environmental protection, surface technology. The growing importance of atmospheric pressure plasma sources will remain in the next years due to the increase of research activities in the mentioned fields as well as the societal challenges (e.g. clean water, clean air, disinfection).

Scientific Department for Plasma Bioengineering

Key aspects

- Study and development of methods for plasma decontamination
- for medical devices, packaging and food up to pilot plant scale
- Investigations of the interaction between plasma and fluids, as well as their effect on microorganisms and biofilms particularly for food applications
- Development of process diagnostics and high-frequency Technology

Work objectives

- Microbiological assessment of plasma processes in particular for issues of biological decontamination
- Development of specific plasma sources and processes for biological decontamination in food and medical applications on the basis of atmospheric pressure plasma sources, particularly microwave-excited plasmas
- Adaption and improvement of methods of laser absorption spectroscopy and microwave interferometry for the measurement of neutral and charged species densities in plasmas
- Design and characterization of microwave plasma sources e.g. for plasma-based sensors for speciation analytics

Work equipment

- Microbiological laboratories of biosafety level 2
- High-frequency and microwave excited plasma sources operating at low and atmospheric pressure
- Setups for laser absorption spectroscopy (e.g. diode laser systems with acusto-optical modulators), systems for laser induced fluorescence measurements
- High-frequency measurement technology (e.g. microwave interferometry up to 150 GHZ, vector network analyzer up to 50 GHz)
- Mass spectrometry and Fourier Transform Infrared spectroscopy (FTIR) for process analysis
- Methods for simulation of high-frequency field distributions

Medium-term focuses

- Consolidation of the interdisciplinary expertise in particular concerning the coupling of plasma physics and biochemistry
- Development and analysis of reactors and processes for plasma cleaning and decontamination in food, packaging and pharmaceutical and medical device area
- Further development of interferometric methods and laser absorption spectroscopy for the determination of species densities particularly in atmospheric pressure plasmas

Technological benefits

The targeted use of methods in plasma decontamination can open up new possibilities in food hygiene in the context of increasing globalization of trade flows as well as an increase in safety expectations for food hygiene. New technologies in the antimicrobial treatment of medical devices can help to reduce risks within an ageing society. New diagnostic approaches as e.g. the AOM technology offer the chances to monitor and control technical processes precisely to ensure sustainability

Scientific Department for Plasma Life Science

Key aspects

- Investigations of the inactivation of microorganisms by plasma
- Investigations of plasma effects for medical applications (in vitro, in vivo and ex vivo tests)
- Molecular analyses of plasma triggered effects (genomic, proteomic to functional approaches) (bottom-up as well as top down)
- Testing of new plasma sources according to standardised methods
- Probing of new approaches in plasma technology, e.g. in biopharmacy and biotechnology

Work objectives

- Microbiological assessment of plasma processes with special focus on plasma medicine and decontamination
- Understanding molecular pathways of plasma triggered processes
- Understanding the different responses of eukaryotic cells, tissue and microorganisms towards plasma
- Backing of clinical results/experiments using plasma sources with fundamental research expertise and in vitro data (biomarker fishing)

Work equipment

- Microbiological and molecular/cell biological laboratories of biosafety level L2/S2
- Atmospheric pressure plasma sources and certified plasma source kinpenMED®
- Expertise and equipment for nucleic acid analyses: microarray, real time PCR, Thermocycler, Bioanalyser, Hybridisation oven, scanner for gene expression chips
- Expertise and equipment for protein analyses: Western Blot, 1D and 2D Gel electrophoresis, fluorescence and confocal microscopy, surface plasmon resonance analysis (Biacore), nanoLC-high resolution mass spectrometry, flow-cytometric multi-plex assay analysis (Luminex), flow cytometry, capillary protein electrophoresis
- Expertise and equipment for functional analyses: cell migration, cell proliferation, signal transduction, enzyme kinetics, atomic force microscopy, tissue histology

Medium-term focuses

- Further development of new applications in the field of plasma medicine
- Consolidation and in-depth accompanying research to clinical plasma applications
- Establishment of (further) standard procedures for plasma medical treatments
- Combination of plasma with other biophysical methods in order to gain synergistic effects

Technological benefits

The area of experimental plasma medicine in close vicinity to plasma physicists attracts increasingly medical personal and opens up new fields of applications. Concomitant development of new medical plasma devices will follow, fostered by the increased understanding of the plasma mediated effects.

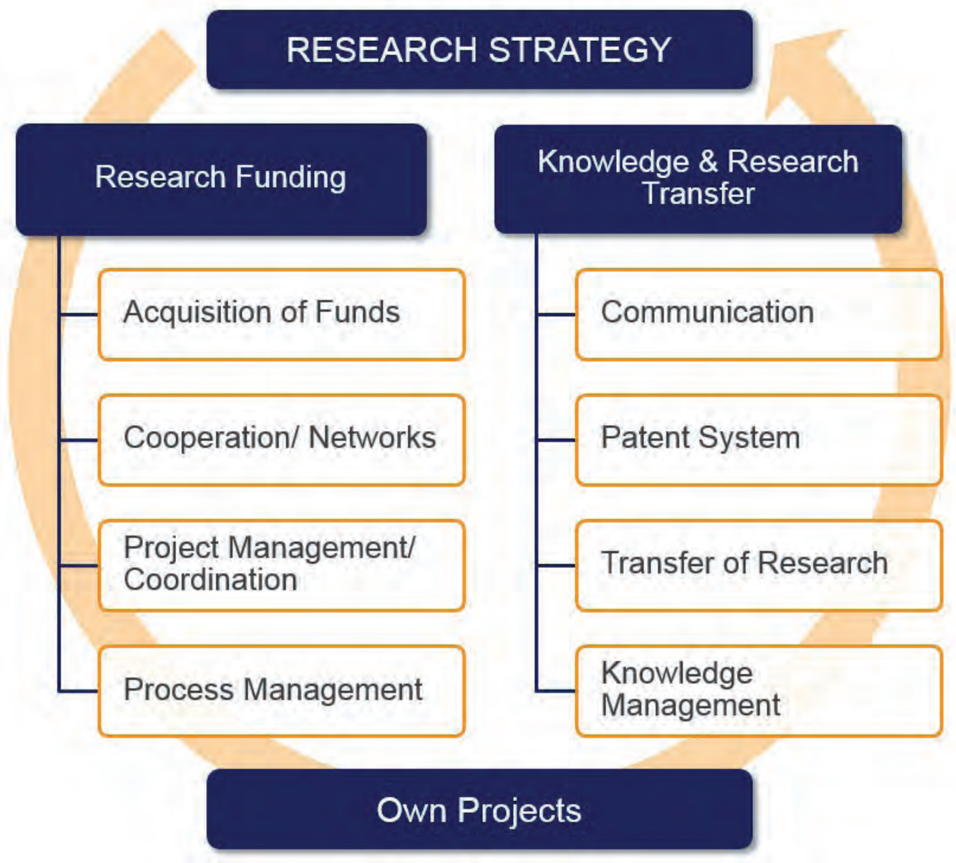
MANAGEMENT SUPPORT

MANAGEMENT SUPPORT
Modern research institutions require a professional research management. Since 2007 the INP Greifswald has installed an appropriate department, the so-called Management Support.

The Management Support gives advice to the board of directors, the research division managers, and the research program managers in the area of research strategy and patent law issues. The department has the task to support the scientists in fund-raising and provides information about open calls and respective guidelines. The Management support is partly responsible for the compilation of funding proposals. Additionally, the Management Support is responsible for the external communication and the patent system at INP to support technology and knowledge transfer issues. Besides the management of own projects they optimize the process management.

Due to this range of activities that are being covered by the Management Support, the scientists are able to focus on their original task: Science. The management Support team considers that it's an active and efficient service provider. The team acts in close cooperation with the board of directors, the scientific managers and the administration.
Tasks in brief:

- Consultation for Research strategy
- Acquisition of third-party funds
- Management of own projects
- Coordination of large-scale projects
- Science communication
- Patent system and exploitation of results
- Management of processes



The key task of the "Department of Administration" is to support the scientific departments by ensuring the accurate handling of all operational processes and business operations. Approximately 20 employees work in the department which covers 5 areas: "Human resources", "Finance/Controlling", "Infrastructure", "IT" as well as the "Legal Affairs".

Administration

All matters concerning the support of the approximately 180 employees run together in the „Human Resources" where all activities relating to the Institute's most important resource – the employees – are coordinated and drawn up. The main task is the preparation of contracts including legal assistance, applicant management (with more than 400 applications p.a.), salary accounting, calculation of human resources as well as statistical reports at federal state and national level.

The whole funding of the institute is managed by the Finance and Controlling team that is divided into purchasing, accounting, external funding and travel management. More than 1.700 order processes and about 1.100 travel orders are handled per annum. The bookkeeping manages the transfer of almost 17 million Euro in more than 200.000 remittances as well as the documentation of all appropriate supporting documents in accordance with the applicable federal, state, provincial and local laws and regulations. The External Funding team deals with on average 50 different research projects with an annual funding of 50.000 up to 2 million Euro.

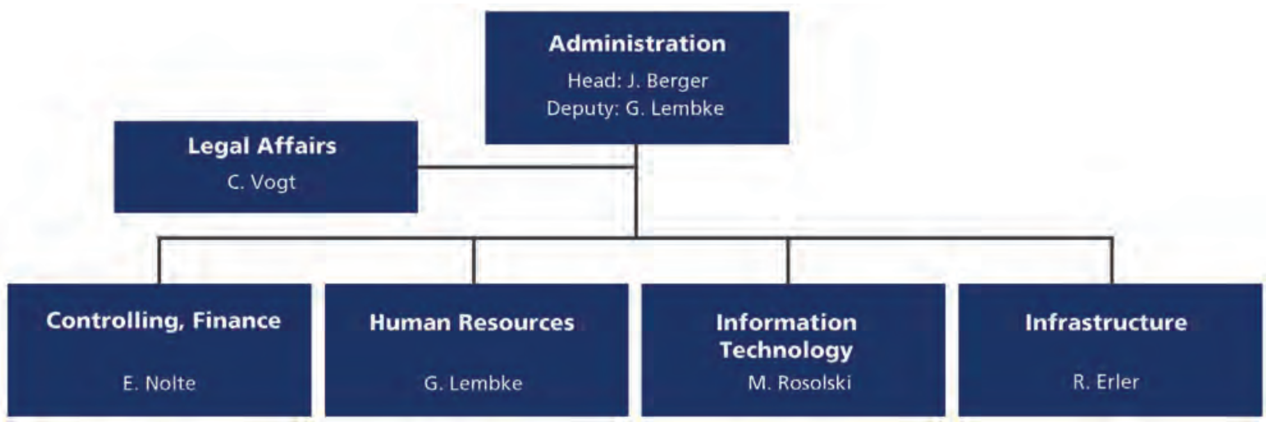
Infrastructure

The Infrastructure regard themselves as reliable service providers for the Scientific Departments and all related areas of the INP.

The Electronic, Mechanical and Glass Blowing workshops develop and construct equipment for research in close cooperation with the scientific staff. Furthermore, they are responsible for repair and conversion work of existing equipment.

The IT provides a highly available data, network and server infrastructure, thereby securing the electronic processes and communication both internally and with external partners of the INP. Furthermore, nearly 600 network-enabled devices such as personal and measuring computers, notebooks, phones and printers are supported by the IT. At the moment, research data with a volume of 50TB are securely stored on the server.

The Facility management deals with the maintenance of the institute's buildings, grounds and facilities as well as construction measures, caretaker and cleaning services. Subject-specific officers (for hazardous materials, fire protection, electrical safety etc.) coordinate and monitor compliance with the directives for safety and health protection and are authorized to give orders on behalf of the Board of Directors.



Bilateral cooperations with industry are not listed

NATIONAL COOPERATIONS

- Albutec GmbH, Rostock
  Fr. Stange
  WK Centifluidic

- Beckmann-Institut für Technologieentwicklung e.V., Oelsnitz/Erzgebirge
  Dr. Meyer
  WK Centifluidic

- C3 e.V.
  Dr. Lieboldt

- Charité Berlin
  Klinik für Dermatologie, Venerologie und Allergologie
  Prof. Lademann

- Christian-Albrechts-Universität zu Kiel
  Institut für Experimentelle und Angewandte Physik
  Prof. Kersten

- CINOGY GmbH, Duderstedt
  Dirk Wandke

- Cytocentrics Bioscience GmbH, Rostock
  Dr. Huber
  WK Centifluidic

- Deutsche Zentralbibliothek für Wirtschaftswissenschaften (ZBW)
  Prof. Tochtermann

- Dockweiler AG
  Hr. Neth
  WK Centifluidic

- DST Diagnostische Systeme & Technologien GmbH, Schwerin
  Hr. Dangers
  WK Centifluidic

- Ernst-Moritz-Arndt-Universität Greifswald
  Institut für Immunologie und Transfusionsmedizin, Abtg. Immunologie
  Prof. Dr. med. Bröker

- Ernst-Moritz-Arndt-Universität Greifswald
  Institut für Mathematik und Informatik
  Prof. Kugelmann

- Ernst-Moritz-Arndt-Universität Greifswald
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- Ernst-Moritz-Arndt-Universität Greifswald
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- Ernst-Moritz-Arndt-Universität Greifswald
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  Dr. Buttkewitz

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  Plasma Medicine Laboratory
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  Institute of Physical and Applied Chemistry, Faculty of Chemistry,
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  Hr. Zinkl

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  Dr. Machala

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- Costa Rica institute of Technology
  Plasma Laboratory for Fusion Energy and Applications
  Dr. Laura Barillas-Mora

- Dublin City University, UK
  National Centre for Plasma Science Technology
  Prof. Turner

- Ecole Polytechnique, Palaiseau, France
  Laboratoire de Plasma Physics
  Dr. Rousseau

- EMPA - swiss federal laboratories for material science and technology
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  Key Laboratory of Multi-Organ Combined Transplantation
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  Research Institute for Electronic Science
  Prof. Misawa

- Holon Institute of Technology, Israel
  Faculty of Science
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  Dr. Donkó

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  Dr. Batrakov

- Institute of Nuclear Chemistry and Technology, Warszawa, Poland
  Prof. Chmielewski

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  Dr. Savastenko

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  Prof. Martuzevicius

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  Department of Electrobiological Physics, Department of Plasma Bioscience Display, Department of Defence Acquisition
  Prof. Eun Ha Choi

- Peking University, China
  BioMed-X Center
  Prof. Fang, Assoc. Prof. Zhang

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  Department of Physics
  Prof. Graham

- Riga Technical University, Latvia
  Prof. Blumberga

- Southern Methodist University, Dallas, Texas
  BioMicroFluidics Laboratory
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  Department of Electrical Engineering
  Prof. Frolov

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  Materials Science and metallurgy department
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  Risoe National Laboratory for Sustainable Energy
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- Zhejiang University of Technology, China
  State Key Laboratory Breeding Base of Green Chemistry-Synthesis Technology
  Prof. Xu, Dr. Ping

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2. Brandenburg, R.: **Memory Mechanisms in Dielectric Barrier Discharges and its Role for Discharge Operation** Plasma Processing Science Gordon Research Conf., Smithfield/USA 2014 eingeladener Vortrag

3. Brandenburg, R.: **Diagnostics of barrier discharges with focus on single filaments** Seminarvortrag eingeladener Vortrag

4. Brandenburg, R.: **Diagnostics of filamentary plasmas: Discharge development and basic plasma parameters** Seminarvortrag eingeladener Vortrag

5. Brandenburg, R.: **Grundlagen und Stand der Technik zur plasmagestützten Abluftbehandlung** Seminarvortrag eingeladener Vortrag

6. Fricke, K.; Quade, A.; Weltmann, K.-D.; Polak, M.: **Biofunctional surface finishing by the use of different plasma jet systems at atmospehric pressure** COST Action MP1101 Biomat. Surf., Bohinjska Bistrica/Slovenia 2014 eingeladener Vortrag

7. Fröhlich, M.: **Reactive magnetron sputtering – the effect of target poisoning on substrate heating** 14th PSE, Garmisch-Partenkirchen/Germany 2014 eingeladener Vortrag

8. Gött, G.; Uhrlandt, D.: **How to convert high-speed images of a welding arc in to time-resolved 2D temperature profiles** CWA Conf., Vancouver/Canada 2014 eingeladener Vortrag

9. Harhausen, J.; Loffhagen, D.; Foest, R.; Ohl, A.: **Charakterisierung von Prozessen zur plasmaionengestützten Schichtabscheidung** DPG Frühjahrstagung Plasmaphysik, Berlin/Deutschland 2014 eingeladener Vortrag

10. Hasse, S.; Tran, T.D.; Hahn, O.; Kindler, S.; Metelmann, H.-R.; Weltmann, K.-D.; Masur, K.: **Plasma treatment of human skin tissue** 4th Int. Symp. for Plasma Biosciences, Seoul/Korea 2014 eingeladener Vortrag

11. Hoder, T.: **Laboratory investigation of streamers under upper atmosphere conditions** Seminarvortrag eingeladener Vortrag

12. Iseni, S.; Reuter, S.; Weltmann, K.-D.: **Laser based spectroscopy, PLIF. Atm. Pres. Plasma jets: turbulent vs laminar** 20th Int. Conf. on Gas Discharges and their Applications, Orléans/France 2014 eingeladener Vortrag

13. Kolb, J.F.: **Degradation of stable pharmaceutical residues in water by nanosecond pulsed corona discharges in water** ISNTP-9, Dalian/China 2014 eingeladener Vortrag

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16. Reuter, S.; Schmidt-Bleker, A.; Tresp, H.; Winter, J.; Iseni, S.; Hammer, M.; Dünnbier, M.; Weltmann, K.-D.: **Interaction of Atmospheric Pressure Plasma Jets with Liquids** 26th Symp. on Plasma Physics and Technology, Prague/Czech Republic 2014 eingeladener Vortrag

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18. Röpcke, J.: **On recent progress in monitoring of technological plasmas using infrared absorption spectroscopy** Colloque du Laboratoire d'Excellence SEAM, Paris/France 2014 eingeladener Vortrag

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23. Uhrlandt, D.: **Investigation of TIG arcs with a non-equilibrium model and optical diagnostics** 4th Int. Round Table on Thermal Plasmas for Industrial Applications, Marrakech/Morocco 2014 eingeladener Vortrag

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26. von Woedtke, Th.: **Plasma medicine: an application of plasma-liquid interaction** Workshop on Gas/Plasma-Liquid Interface, Leiden/Netherlands 2014 eingeladener Vortrag

27. von Woedtke, Th.: **Plasma medicine: state and perspectives** 15th Latin American Workshop on Plasma Physics, San Jose,/Costa Rica 2014 eingeladener Vortrag

28. Weltmann, K.-D.; Bussiahn, R.; Ehlbeck, J.; Gerling, T.; Polak, M.; Schnabel, U.; v. Woedtke, Th.: **Plasmas in medicine – from surface modification to direct therapeutic use** 14th PSE, Garmisch-Partenkirchen/Germany 2014 eingeladener Vortrag

29. Weltmann, K.-D.; Gerling, T.; Höft, H.; Hoder, T.; Pipa, A.; Nastuta, A.V.; Brandenburg, R.; Bussiahn, R.; Kettlitz, M.: **Advanced Electrical and Optical Diagnostics on Atmospheric Pressure Plasmas with Focus on Microdischarges** 20th Int. Conf. on Gas Discharges and their Applications, Orléans/France 2014 eingeladener Vortrag

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1. Baeva, M.: **Chemical and thermal non-equilibrium effects in free-burning arcs** 22nd ISPC, Antwerp/Belgium 2015 eingeladener Vortrag

2. Brandenburg, R.; Höft, H.; Kettlitz M.; Bogaczyk, M.; Weltmann K.-D.: **Novel insights in the development of dielectric barrier discharges** 20th Symp. on Application of Plasma Processes, Tatranská Lomnica - Vysoké Tatry/Slovakia 2015 eingeladener Vortrag

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4. Brüser. V.; Peglow, S.; Sievers, G.; Junge, H.; Kruth, A.: **Plasma-Enhanced Synthesis of Nanostructured Photo and Eletrocatalyst Materials for Solar and Fuel Cell Applications** 10th Asian-European International Conference on Plasma Surface Engineering, Jeju/Korea 2015 eingeladener Vortrag

5. Ehlbeck, J.; Schnabel, U.; Andrasch, M.; Stachowiak, J.; Stolz, N.; Weltmann, K.-D.: **Plasmabehandlung von Lebensmitteln** 17. Fachtagung Plasmatechnologie, Kiel/Deutschland 2015 eingeladener Vortrag

6. Fricke, K.: **PECVD von Funktionsschichten in Atmosphärendruckplasmen für Anwendungen in der Medizintechnik und Biotechnologie** 17. Fachtagung Plasmatechnologie, Kiel/Deutschland 2015 eingeladener Vortrag

7. Gerling, T.; Brandenburg, R.; Weltmann, K.-D.: **Plasma Sources at the INP** 2nd COST TD1208 Training School, Greifswald/Germany 2015 eingeladener Vortrag

8. Gortschakow, S.; Franke, S.; Gött, G.; Khakpour, A.; Kozakov, R.; Methling, R.; Uhrlandt, D.; Weltmann, K.-D.: **Use of optical diagnostics for characterisation of switching and welding arcs** 1st Sino-German Symp. on Atmospheric Pressure Gas Discharges and Plasma Applications, Beijing/China 2015 eingeladener Vortrag

9. Harhausen, J.; Loffhagen, D.; Foest, R.: **Charakterisierung des PIAD-Plasmas – aktueller Stand und neue Ansätze** DPG Frühjahrstagung Plasmaphysik, Bochum/Deutschland 2015 eingeladener Vortrag

10. Kolb, J.F.: **Cold DC Operated Air Plasma Jet for the Inactivation of Infectious Microorganisms** 1st Sino-German Symp. on Atmospheric Pressure Gas Discharges and Plasma Applications, Beijing/China 2015 eingeladener Vortrag

11. Kolb, J.F.: **Nanosecond Pulsed Electric Fields For Novel Medical And Environmental Applications** 20th IEEE Int. Pulsed Power Conf., Austin/USA 2015 eingeladener Vortrag

12. Kolb, J.F.: **Bioelectrics: Nanosecond Pulsed Electric Fields for Medical and Environmental Applications** DPG Frühjahrstagung Plasmaphysik, Bochum/Deutschland 2015 eingeladener Vortrag

13. Kolb, J.F.; Brandenburg, R.; Ehlbeck, J.; von Woedtke, T.; Weltmann, K.-D.: **Plasmatechnologie für die Dekontamination** V2015 Vakuumbeschichtung & Plasmaoberflächentechnik, Dresden/Deutschland 2015 eingeladener Vortrag

14. Kristian Wende, Anke Schmidt, Sander Bekeschus, Sybille Hasse, Michael Lalk, Kai Masur, Thomas von Woedtke **Cold atmospheric plasma - a future therapeutic approach?** Jahrestagung der Deutschen Pharmazeutischen Gesellschaft, Düsseldorf/Deutschland 2015 eingeladener Vortrag

15. Lang, N.; Macherius, U.; Glitsch, S.; Zimmermann, H.; Röpcke, J.; van Helden, J. H.: **Quantitative in situ process monitoring in plasma technology using quantum cascade laser absorption spectroscopy** 2nd Int. Workshop Diagnostic Systems for Plasma Processes, Lichtenwalde/Germany 2015 eingeladener Vortrag

16. Lang, N.; Macherius, U.; Zimmermann, H.; van Helden, J. H.; Röpcke, J.: **In situ monitoring industrieller Plasmaprozesse in der Plasmatechnologie mit Quantenkaskadenlaser-Absorptionsspektroskopie** 17. Fachtagung Plasmatechnologie, Kiel/Deutschland 2015 eingeladener Vortrag

17. Masur, Kai **References and Standardization in Plasma Medicine** 5th Intern. Symp. on Plasma Science, Jeju/Korea, 2015 eingeladener Vortrag

18. Masur, Kai, Stephan Reuter, Kristian Wende, Thomas von Woedtke, Klaus-Dieter Weltmann **Towards a better comparison of plasma sources for biomedical applications: references and safety measurements** Materials Research Society Fall Meeting, Boston/USA 2015 eingeladener Vortrag

19. Masur, Kai; Magdalena von Behr, Klaus-Dieter Weltmann, Ivo Partecke, Thomas von Woedtke **COMBINATION OF TUMOR THERAPEUTICS AND COLD PLASMA TO FIGHT CANCER** IEEE Int. Conf. on Plasma Sciences, Belek/Turkey 2015 eingeladener Vortrag

20. Miron, C.: **Structural Modifications of Materials by Plasma Discharges in Liquids** 1st Sino-German Symp. on Atmospheric Pressure Gas Discharges and Plasma Applications, Beijing/China 2015 eingeladener Vortrag

21. Miron, C.; Zhuang, J.; Sava, I.; Hulubei, C.; Weltmann, K.-D.; Kolb, J.F.: **Surface Modification of Materials Treated by Nanosecond Pulsed Driven Electrical Discharges in Liquids** 7th Int. Symp. on Advanced Plasma Science and its Applications for Nitrides and Nanomaterials, Nagoya/Japan 2015 eingeladener Vortrag

22. Polak, M.: **Kombinationsverfahren von gepulstem Magnetronsputtern und Ionen Implantation zur Erzeugung bioaktiver Oberflächen** 17. Fachtagung Plasmatechnologie, Kiel/Deutschland 2015 eingeladener Vortrag

23. Reuter, S.; Bekeschus, S.; Dünnbier, M.; Hammer, M.; Hasse, S.; Iseni, S.; Jablonowski, H.; Masur, K.; Schmidt, A.; Schmidt-Bleker, A.; Woedtke, T. V.; Wende, K.; Winter, J. and Weltmann, K.-D.: **Reactive Species in Plasma Medicine** 22nd ISPC, Antwerp/Belgium 2015 eingeladener Vortrag

24. Reuter, S.; Schmidt-Bleker, A.; Iseni, S.; Jablonowski, H.; Winter, J.; Weltmann, K.-D.: **Diagnostics of Atmospheric Pressure Plasma Jets** 68th Gaseous Electronics Conf., Honolulu/Hawaii 2015 eingeladener Vortrag

25. Reuter, S.; Schmidt-Bleker, A.; Iseni, S.; Winter, J.; Jablonowski, H.; Weltmann, K.-D.: **LIF spectroscopy on cold Plasma Jets for Plasma Medicine** 17th LAPD, Hokkaido/Japan 2015 eingeladener Vortrag

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27. Reuter, S.; Schmidt-Bleker, A.; Jablonowski, H.; Winter, J.; Iseni, S.; Woedtke, T. V. and Weltmann, K.-D.: **Interaction of pasma jets with liquids for biomedical applications** 6th CESPC, Bressanone/Italy 2015 eingeladener Vortrag

28. Röpcke, J.: **Infrarot-Absorptionsspektroskpopie an Plasmen für industrielle Anwendungen** EFDS-Workshop "Diagnostik von Prozessplasmen", Dresden/Deutschland 2015 eingeladener Vortrag

29. Sun, A.; Becker, M.M.; Loffhagen, D.: **Particle based simulations of low temperature plasma discharges.** 1st Sino-German Symp. on Atmospheric Pressure Gas Discharges and Plasma Applications, Beijing/China 2015 eingeladener Vortrag

30. Uhrlandt, D.: **Extended Methods of Emission Spectroscopy for the Analysis of Arc Dynamics and Arc Interaction with Walls** 21th Symp. on Physics of Switching Arc, Brno/Czech Republic 2015 eingeladener Vortrag

31. van Helden, J. H.; Hübner, M.; Nave, A.; Lang, N.; Davies, P. B.; Röpcke, J.: **Quantum cascade laser absorption spectroscopy for the detection of transient species in plasmas** DPG Frühjahrstagung Plasmaphysik, Bochum/Deutschland 2015 eingeladener Vortrag

32. van Helden, J. H.; Lang, N.; Macherius, U.; Zimmermann, H.; Glitsch, S.; Wiese, M.; Röpcke, J.: **On recent progress applying quantum cascade lasers in sensing for environmental and plasma diagnostics** OSA-Meeting: Optics and Photonics for Energy and the Environment, Suzhou/China 2015 eingeladener Vortrag

33. van Helden, J. H.; Lang, N.; Röpcke, J.: **Quantitatives Prozessmonitoring in der Plasmatechnik** 23. NDVaK, Dresden/Deutschland 2015 eingeladener Vortrag

34. von Woedtke, Th.: **Cold atmospheric plasma for medicine: State of research and clinical application** 68th Gaseous Electronics Conf., Honolulu/Hawaii 2015 eingeladener Vortrag

35. von Woedtke, Th.: **Clinical application of cold atmospheric plasma - state and perspectives** 22nd ISPC, Antwerp/Belgium 2015 eingeladener Vortrag

36. Weltmann, K.-D.; Andrasch, M.; Baeva, M.; Bösel, A.; Schnabel, U.; Ehlbeck, J.: **Microwave induced plasmas and their potential applications in food industry** IMPI 49, San Diego/USA 2015 eingeladener Vortrag

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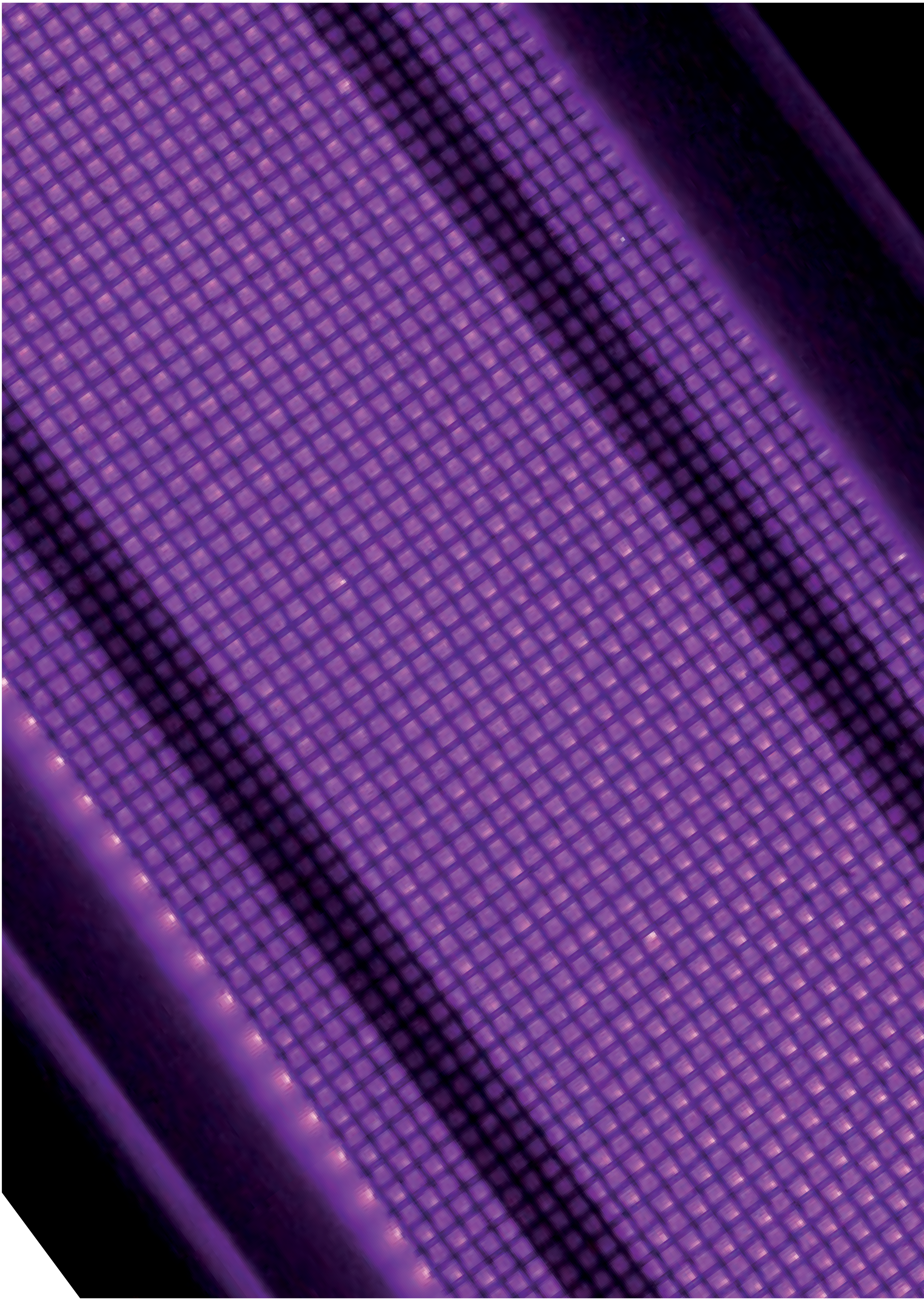

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