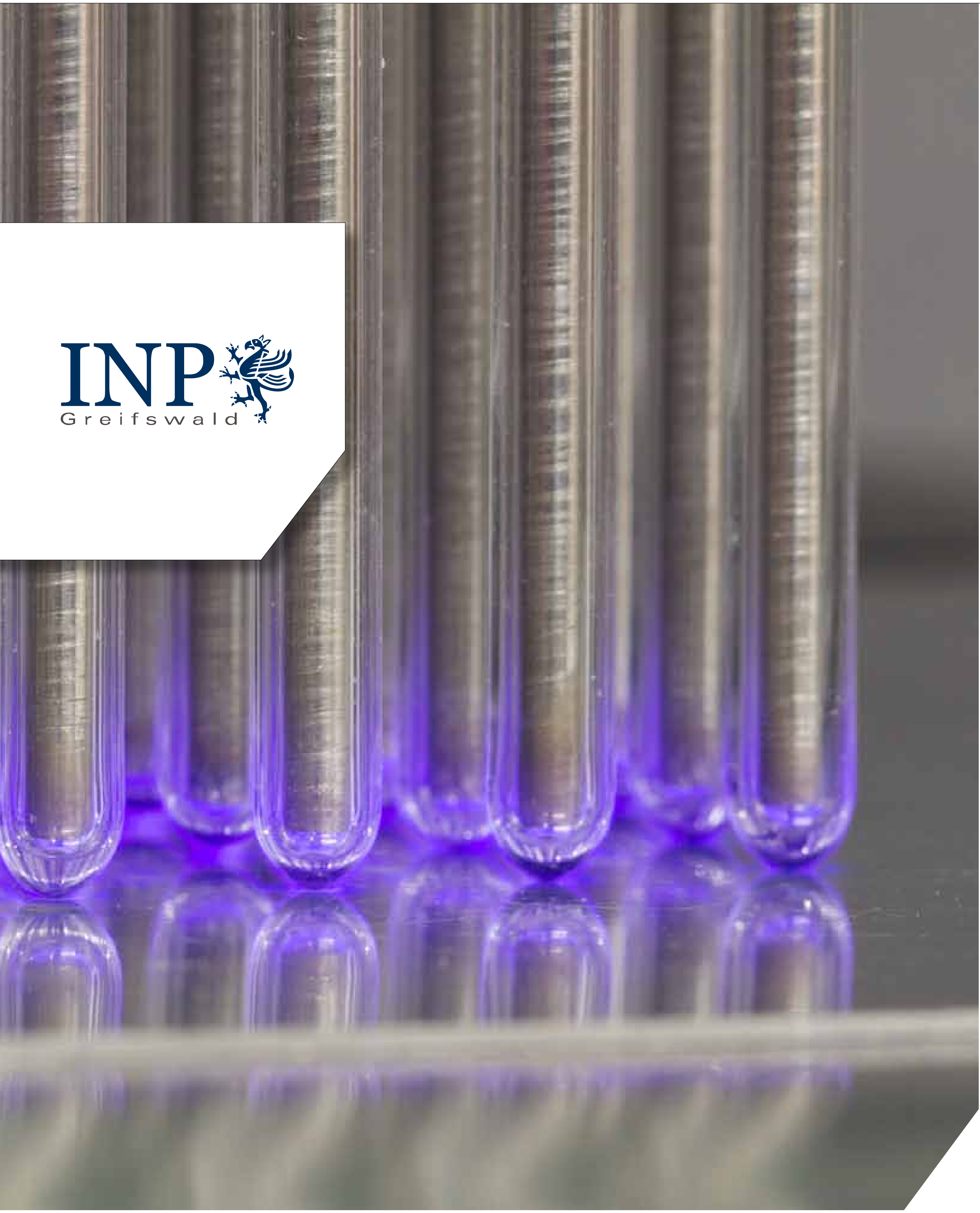
BIENNIAL REPORT 2012/2013

LEIBNIZ INSTITUTE FOR PLASMA SCIENCE AND TECHNOLOGY



INP Greifswald

BIENNIAL REPORT 2012/2013

LEIBNIZ-INSTITUTE FOR PLASMA SCIENCE AND TECHNOLOGY

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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, which is based on a combination of excellent knowledge-oriented basic research and application-oriented industrial feasibility.

Interdisciplinary research is the key to accept technological challenges in this day and age. Thus physicists, mathematicians, chemists, biologists, engineers and pharmacists work closely together to gain a better understanding of the complexity of processes under investigation. Excellent facilities are crucial to do so. On this basis the INP was able to open up new fields of applications for plasma technology, i.e. in the field of life science. In parallel, the number of scientific publications raised and so the international visibility of the INP was increased. For securing this high level of research further education of young academics is of high priority for the INP Greifswald.

We received an outstanding confirmation of the institutes' efforts during the visit of our Federal President Joachim Gauck accompanied by the prime minister of Mecklenburg-Vorpommern Erwin Sellering on May 25th, 2013. The Federal President concluded: "Such scientific lighthouses show, that the state does not drag behind, but acts on the forefront of progress".

This remark made us proud of our achievements and let us look ahead highly motivated.

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

The key aspects of the INP were consolidated and combined based on the annual strategic revision and recommendation of the Scientific Advisory Council in 2012. Since 2013 the INP Greifswald thematically and organizationally operates with two Research Divisions using their specific expertise. The Research Divisions are responsible for further focusing of research topics, their network and usage of resulting alliances.

The historical origin of gas discharges physics was a combination of electrical engineering and plasma technology. This unique combination of research fields is revived in the Research Division "Plasmas for Materials & Energy" at the INP Greifswald to allow new experimental and theoretical approaches. The capability of cross-linking is shown with the use of plasma surface technology to increase durability of electrotechnical installations or in the application of complex plasma models considering non-equilibrium characteristics to support the development of switchgear installations.

The Research Division "Plasmas for Environment & Health" focusses on interdisciplinary topics. Collaborations between Decontamination, Plasma Medicine, Pollution Degradation, Bioactive Surfaces and Bioelectrics are based on atmospheric pressure plasma sources, which are extensively studied. This concept of a unique union of physicists, mathematicians, chemists, biologists, engineers and pharmacists is already copied in the Asian region, and intensified national cooperations with universities and colleges support the concept.

The realignment of the Research Divisions resulted in a further focusing on main topics and aims at achieving thematic leaderships in specific research areas, a consistent appointment of highly qualified scientists and top executives as a unique characteristic, an increased number of scientific articles, successful transfer of research results into businesses and developing new research topics.

In the past two years the INP Greifswald placed emphasis on creating equipment-related conditions for interdisciplinary research.

The appointment of a second W3 professorship (Prof. Schoenemann) enabled us to provide laboratories with high-voltage and high current equipment. Especially a recently commissioned laboratory was equipped with two special high current generators for switching arcs investigations. Developing state-of-the-art switch gears in regard to environmental aspects is inconceivable without physically-based simulations of plasma and accompanying experiments.
A laboratory for generating ultrashort high-voltage pulses, high electric field strengths and pulsed plasmas including diagnostics to examine medical and environmental applications was established with the appointment of the W2 professorship of Bioelectrics (Prof. Kolb). The Research Programme Bioelectrics studies the interaction of cells with electrical stimuli. Morphological and functional changes of cells, viable tissues and organs could be obtained depending on the applied method and selected parameter.

The new Scientific Department "Plasma Bioengineering" was founded on 1 January 2012. The team develops methods and procedures for the plasma-based decontamination and applications in plasma medicine. The main focus is on implementing the innovative procedures of plasma-based decontamination into industrial applications. They apply microbiological methods to quantify the efficiency of their developed procedures and examine new methodical approaches for plasma-diagnostics and analytics. The new Scientific Department is headed by the former head of "Plasma Diagnostics", Dr. Jörg Ehlbeck.

Since 1 October 2012 the Research Programme "Bioactive Surfaces" is headed by Dr. Martin Polak. The team of "Bioactive Surfaces" develops plasma-based processes for refinement of material surfaces for biomedical purposes like polymers, metal, ceramics and glass. The Research Programme "Welding/Switching", former headed by Dr. Dirk Uhrlandt, was handed over to Dr. Sergej Gorchakov on 1 November 2012. The Research Programme studies thermal plasmas and their technical applications.

The INP Greifswald satisfies its claim to train also the institute's own scientific leaders with these two promotions.

In 2013 the BMBF-funded major project "Campus PlasmaMed", a research association founded to explore promising and safe applications of atmospheric pressure plasmas in medical therapy, was successfully completed (see also page 18). During the project 148 scientific articles were published by the research alliance. Additionally a clinical study was successfully completed, and five laboratory prototypes and a certified medical device were developed in cooperation with external partners. In order to ensure the sustainability of the project, to pursue the scientific work and to remain and expand the center of plasma medicine in Mecklenburg-Vorpommern, the Ministry of Education, Science and Culture funds the INP Greifswald with 1.5 Mio Euro. The project aims at an extension of scientifically accompanied and supported tests for therapeutical applications of atmospheric pressure plasma sources in dermatology and dentistry. The field of applications will be broadened with new areas like facial surgery and pulmonology. Plasma pharmacy is also a new field of research, which will be further developed based on gained knowledge about the influence of liquids in mediating biological plasma effects.

General information

The Leibniz Institute for Plasma Science and Technology e.V. (INP) conducts application-oriented basic research in the fields of low-temperature plasmas and plasma technologies within the Research Division of Plasmas for Materials and Energy and the Research Division of 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 the requirements in research and development and the 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.

According to the 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

Research Division: Plasmas for Materials and Energy with the Research Programmes:
- Surfaces and Thin Films
- Catalytic Materials
- Process Monitoring
- Welding and Switching

Research Division: Plasmas for Environment and Health with the Research Programmes:
- Bioactive Surfaces
- Plasma Medicine and Decontamination
- Pollutant Degradation
- Bioelectrics

Board of Trustees

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

Members (Status 2013)

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 2013)

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

Prof. Dr. Holger Kersten (Deputy Chair)
Christian Albrechts University of Kiel

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

Prof. Dr. Kurt Becker
Polytechnic Institute of New York University

Dr. Uwe Kaltenborn
Maschinenfabrik Reinhausen GmbH, Regensburg

Prof. Dr. Jürgen Meichsner
Ernst Moritz Arndt University of Greifswald,
Institute of Physics

Ernst Miklos
The Linde Group, Unterschleißheim

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

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 2013)

Mario Kokowsky (Chair)
Technologiezentrum Fördergesellschaft mbH Vorpommern, Greifswald

RD. Nicole Kraheck
Federal Ministry of Education and Research

Woldemar Venohr
Ministry of Education, Science and Culture,
Mecklenburg-Western Pomerania

Dr. med. Dagmar Braun
Braun Beteiligungs GmbH, Greifswald

Werner Mlodzianowski
ttz Bremerhaven

Prof. Dr. Günter Ecker
Ruhr University Bochum

Prof. Dr. Holger Fehske
Ernst Moritz Arndt University of Greifswald,
Institute of Physics

Prof. Dr. Jürgen Meichsner
Ernst Moritz Arndt University of Greifswald,
Institute of Physics

Prof. Dr. Ulrich Schempp
Stralsund University of Applied Sciences

OB Dr. Arthur König
University and Hanseatic City of Greifswald

Dr. Ulrich Kogelschatz
Formerly at ABB AG

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

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. 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, in part, 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.

Plasma Diagnostics

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

Surface diagnostics

- High-resolution x-ray photo-electron
- spectroscopy (XPS)
- Energy-dispersive X-ray spectroscopy (EDX)
- FT-infrared spectroscopy
- Atomic force microscope (AFM)
- Scanning electron microscope (SEM)
- Profilometer
- Light microscope with 3D function

Arc 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

Lighting technology laboratory

- Ulbricht sphere
- Compact spectrometer
- Luminance cameras

High-frequency technology

- Reflectometry
- Microwave plasmas with mini-MIP and Plexc
- Frequency-resolved microwave interferometry

Microbiological S2 laboratory

- Phytopathogenic and human pathogenic micro-organisms in risk groups 1 and 2
- Sterile work benches, incubators, transmission micro-scopes with CCD camera

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 2012 amounted to € 15.8 million. Personnel expenditures amounted to € 7.5 million (2012); the cost for supplies was € 3.7 million (2012). In 2012, a total of € 4.0 million was invested in capital equipment of INP.

Staff:
The INP had 194 employees as of July 2013. This is including 108 scientific and technical positions. The number of female employees is equivalent to 24.6 percent.

Main building (new building 1999)

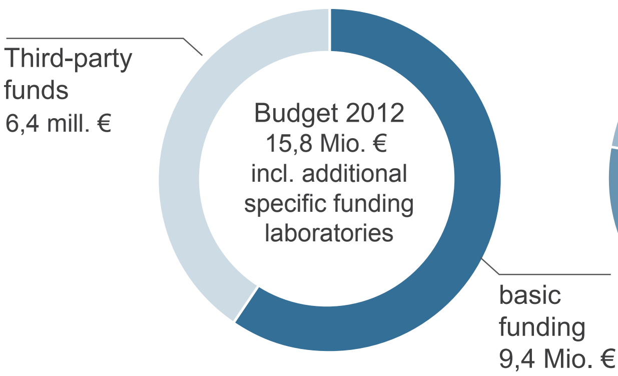
Main floor space 3.700 sqm

130 workstations

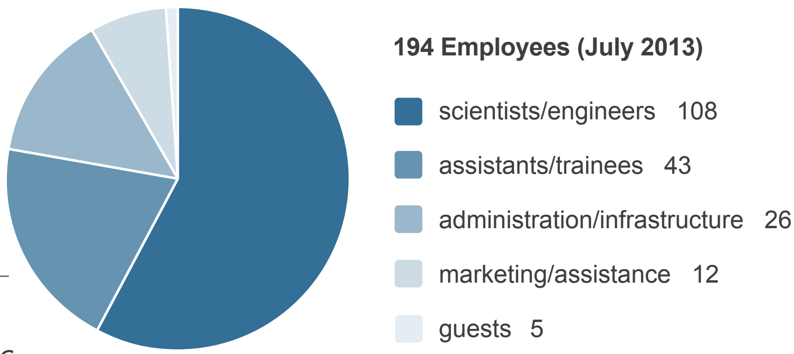
41 laboratories

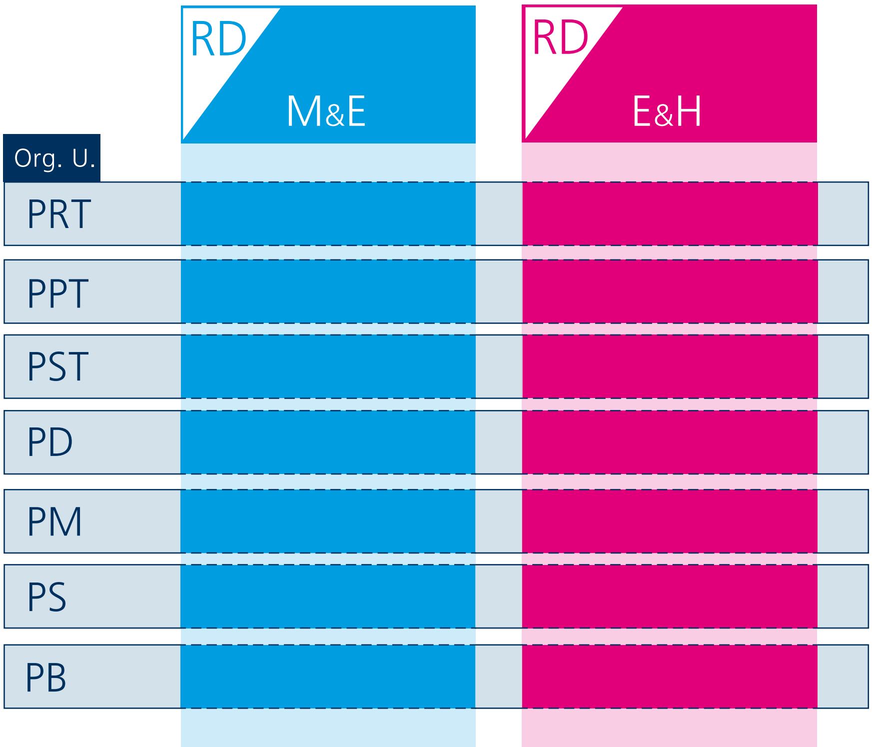
Extension building 540 sqm
(30 workstations, 8 laboratories)

Budget (2012)



Staff (2013)





Matrix structure of the Research Divisions (RD) and Scientific Departments (Org. U.)

Research Divisions Plasmas for Materials & Energy

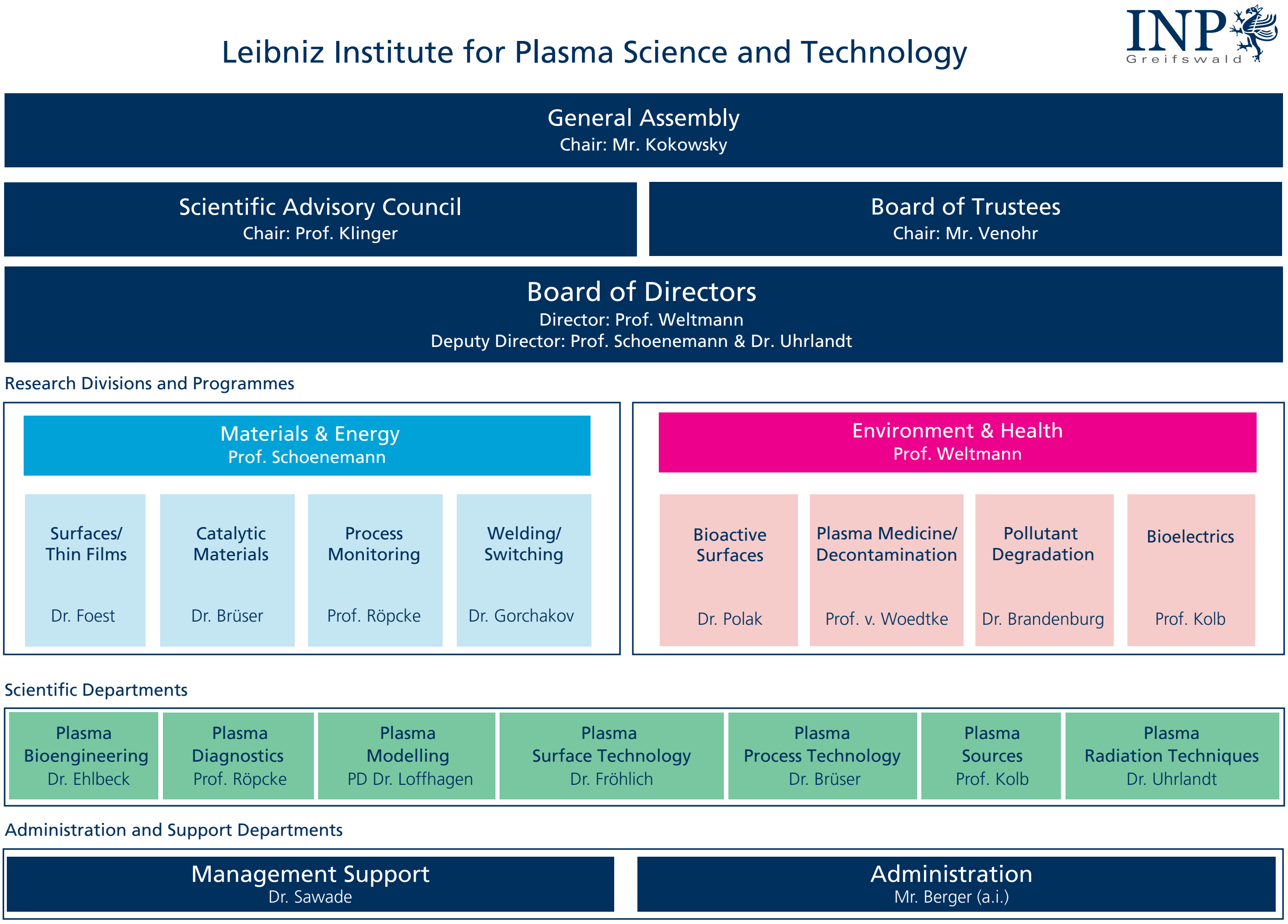
Research Programme Surfaces / Thin Films
Research Programme Catalytic Materials
Research Programme Process Monitoring
Research Programme Welding / Switching

Research Divisions Plasmas for Environment & Health

Research Programme Bioactive Surfaces
Research Programme Plasma Medicine / Decontamination
Research Programme Pollutant Degradation
Research Programme Bioelectrics

Scientific Departments

Plasma Radiation Technology (PRT)
Plasma Process Technology (PPT)
Plasma Surface Technology (PST)
Plasma Diagnostics (PD)
Plasma Modelling (PM)
Plasma Sources (PS)
Plasma Bioengineering (PB)



Organizational chart
of the INP Greifswald (2014).

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.

Cooperation and networks

To carry out its tasks as a center of comprehensive competence for technological applications of plasmas, INP maintains various cooperative relationships and is extensively networked 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 and mathematics, have made it possible to establish successful joint initiatives, such as "Campus PlasmaMed", the Plasmatis Centre for Innovation Competence (ZIK plasmatis) and the project on the trace gas analytical study of human breath in the framework of the "Study of Health in Pomerania (SHIP)". Special recognition deserves the world's first chair for plasma medicine was set up in cooperation between University Medicine Greifswald and INP in 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 Regionale 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. Stralsund University of Applied Sciences is also contributing to the research cluster "Campus PlasmaMed".

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

- Ruhr-Universität Bochum (Ruhr University, Bochum)
- Christian Albrechts University of Kiel
- Rheinisch-Westfälische Technische Hochschule Aachen (Rhine-Westphalia Technical University of Aachen)
- Technische Universität Dresden (Dresden University of Technology)
- Technische Universität Berlin (Technical University of Berlin)
- Institut für Grenzflächenverfahrenstechnik und Plasmatechnologie der Universität Stuttgart (Institute for Interfacial Process Engineering and Plasma Technology at the University of Stuttgart)

Internationally, INP maintains strong cooperative partnerships.

- Université Paul Sabatier/CNRS Toulouse, Centre de Physique des Plasmas & des leurs Applications, Laboratoire de Genie Electrique, Toulouse, France (Paul Sabatier/CNRS University of Toulouse, Centre of Physics and Plasma and their Application, Laboratory of Electrotechnology)
- École Polytechnique, Palaiseau, France (Palaiseau Polytechnical University)
- Cambridge University, Chemical Department, Cambridge, UK,
- Eindhoven Technical University, Netherlands
- Saint-Petersburg State University, Russia
- Masaryk University of Brno, Czech Republic
- Technical University of Prague, Czech Republic, and
- Old Dominion University, Norfolk, VA, USA.

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. Ing. Thomas Schoenemann
University of Rostock - High Voltage and
High Current Engineering

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

BalticNet-PlasmaTec

The technology cluster BalticNet-PlasmaTec supports partners in establishing innovative commercial plasma technologies for the economy. The network operates as an incubator for international cooperation between research and the economy in the field of plasma technology in Northern Europe. One of the main goals of the cluster is to increase the visibility of plasma technologies in society. Meanwhile, 57 partners from 12 countries, including more than half from industry, work under the umbrella of the cluster. Overall, more than 25 projects have been initiated, accompanied or conducted, most of them with active participation of the INP.
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. As part of the network, INP is involved in round robin tests (a laboratory performance test for external quality assurance for measurement procedures).
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. We highly value your co-operation in achieving these objectives!

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

Nationwide Networks

Senior INP employees act on the boards of important networks throughout Germany. These include:
- Association for Plasma Physics (Fachverband Plasmaphysik) of the German Physical Society (DPG)
  www.dpg-physik.de
- German Society for Plasma Technology (DGPT)
  www.dgpt.eu

Nationales Zentrum für Plasmamedizin e.V. (National Centre of Plasma medicine)
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. (Regional economy initiative for the eastern part of Mecklenburg-Vorpommern)
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, and INP is a member of this in the interest of close cooperation with the regional economy.
www.rwi-online.de

Baltic Green HealthCare
The Baltic Green HealthCare Cluster is certified by the European Cluster Innovation Platform and wants to work with its members to promote a sustainable health care economy in the southern Baltic Sea area and possibly in the entire Baltic Sea region in the future. The cluster's areas include topics such as sustainable construction, energy efficiency, waste and sewage. Since the middle of 2013, INP has been a member of the cluster.
www.eco4life.info/baltic-green-healthcare

International Bioelectrics Consortium
INP joined the competence network "International Bioelectrics Consortium" in 2007. It 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.
ww2.odu.edu/engr/bioelectrics/consortium

In an advisory capacity, INP is active in more than 8 working groups or technology alliances, and advises agencies and ministries, etc. 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 research cluster "Campus PlasmaMed", funded by the German Federal Ministry of Education and Research's (BMBF) programme "Spitzenforschung und Innovation in den neuen Ländern" (Leading-edge Research and Innovation in the New German Länder),
- the Plasmatis Centre for Innovation Competence (ZIK plasmatis) with the two junior scientist groups "Cellular Effects" and "Extracellular Effects",
- the BMBF's joint preliminary project "PT Grid – Plasma Technology Grid",
- the DFG-AiF cluster "Arc Welding".

INP has intensified its activities in the acquisition of international projects. It was involved in several EU projects during the reporting period.

In the Interreg **IVb project "PlasTEP"**, 15 partners from eight countries work to develop practical applications based on plasma-based technologies for air and wastewater treatment. Within this project, INP managed a work package and was actively involved in four other work packages.

In the framework of the joint project **"Plasma-based catalytic treatment of exhaust emissions of marine diesel engines"** of the ERA-NET for Maritime Technologies (MARTEC), INP worked with two other German and two Polish partners on the reduction of nitrogen and sulfur oxides in the exhaust of marine diesel engines.

On 1 June 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-Institut für Katalyse e.V. an der Universität Rostock (Leibniz Institute for Catalysis at the University of Rostock)
- Leibniz-Institut für Kristallzüchtung, Berlin (Leibniz Institute for Crystal Growing)
- Leibniz-Institut für Agrartechnik Potsdam-Bornim (Leibniz Institute for Agricultural Technology at Potsdam-Bornim)
- Leibniz-Institut für Gewässerökologie und Binnenfischerei (IGB), Berlin (Leibniz Institute of Freshwater Ecology and Inland Fisheries), and
- Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Berlin (Ferdinand Braun Institute, Leibniz Institute for High Frequency Technology)

Institutes in the Fraunhofer Gesellschaft (Fraunhofer Society) such as

- Fraunhofer-Institut für Schicht- und Oberflächentechnik in Braunschweig (Fraunhofer Institute for Thin Film and Surface Technology in Brunswick)
- Fraunhofer-Institut für Fertigungstechnik und Angewandte Materialforschung, Bremen (Fraunhofer Institute for Manufacturing Technology and Advanced Materials Research)
- Fraunhofer-Institut für Angewandte Optik und Feinmechanik, Jena (Fraunhofer Institute for Applied Optics and Precision Engineering) and
- Fraunhofer-Institut für Werkstoff- und Strahltechnik, Dresden (Fraunhofer Institute for Material and Beam Technology)

the Helmholtz Centers for

- Material and Coastal Research in Geesthacht
- Materials and Energy in Berlin,

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. Leibniz institutes are international leaders in many high-technology fields and promote this process by industry-related research and the transfer of technology. The applications laboratories implement research results in practice-oriented, functional models and demonstrators, thereby creating active interfaces between business and science. The Leibniz application 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).

Appointments and Awards

Exceptional entrepreneurial ideas in the UNIQUE idea competition in Greifswald

Dr. Jörg Ehlbeck from the Scientific Department of Plasma Bioengineering finished in third place and won € 1,000 in the UNIQUE idea competition. Dr. Ehlbeck was able to convince the jury with his entrepreneurial idea for adding plasma-based applications to medical equipment.

Bestowing INP research awards

Two female scientists were awarded the inaugural "INP Research Award" in 2013. The prize honors outstanding scientific publications by scientists at INP each year. Dr. Magarita Baeva was distinguished (Baeva, M.; Kozakov, R.; Gorchakov, S.; Uhrlandt, D.: Two-temperature chemically non-equilibrium modelling of transferred arcs. Plasma Sources Sci. Technol. 21 (2012)) in the category "Senior Research Award",
Dr. Katja Fricke was distinguished (Fricke, K.; Koban, I.; Tresp, H.; Jablonowski, L.; Schröder, K.; Kramer, A.; Weltmann, K.-D.; von Woedtke, Th.; Kocher, T.: Atmospheric Pressure Plasma: A High-Performance Tool for the Efficient Removal of Biofilms. PLoS One 7 (2012)) in the category "Junior Research Award".

Appointments

The range of topics at the INP has been expanded due to two new appointments. Prof. Jürgen Kolb was appointed a W2 professorship in the field of Bioelectrics and set up a laboratory for the generation of ultra short high-voltage pulses, high field strengths and pulsed plasmas (including diagnostics) for the investigation of medical and environmentally relevant applications.

Prof. Thomas Schoenemann was appointed a W3 professorship in the area of High-voltage and High-current Engineering, with special focus on issues of plasma in electrical engineering (e.g. plasmas in switching devices, insulation materials). To this end INP build up laboratories with high-voltage and high-current technology, in particular a laboratory with two special high-current generators for the study of switching arcs, which is still under construction.

Exhibitions

Participation of INP at Phänomenta

In 2014 INP will exhibit at 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.

Strategy process

INP's strategic goal is to be THE center of excellence with respect to the consistent and successful combination of basic and applied research in selected core areas of plasma research in Germany.

Since 2013, INP has bundled fields of work and the associated strategic orientation into two Research Divisions: "Plasmas for Materials and Energy" and "Plasmas for Environment and Health". Both divisions will pursue a focus on scientific core topics, aiming for leadership in select areas as well as the development of new fields.

Unique advantages of INP are:
- exceptional combination of plasma science with biology and medicine, both as a subject of basic research and with respect to application;
- Consistent combination of scientifically sophisticated plasma modelling and spatially and temporally resolved diagnostics with application-oriented electric power engineering (e.g. arcs), supplemented by very modern experimental laboratories;
- Extension of the range of topics in plasma science to the field of bioelectrics utilizing pulsed electric fields and atmospheric pressure plasmas.

Associated with all of these special interest areas, the INP has succeeded to appoint a professorship together with either the University of Greifswald or the University of Rostock. As a result new socially and scientifically highly relevant topics could be adopted and included in the portfolio of the Institute. Thus, scientifically and socially relevant issues in the focus of research activities are now adequately staffed. In addition, this research strategy is complemented by a unique transfer strategy within the Leibniz Association (WGL), which has led to three spin-offs. These companies successfully operate on the market in the areas of technology transfer/technology marketing, analytical instrumentation/plasma sources and medical devices and have created additional jobs.

Participation in Research Alliances and Working Groups 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. The research alliances use inter- and transdisciplinary approaches to address current scientific and socially-relevant issues.

Leibniz Research Alliance for Energy Change

The German energy system is facing the most serious change in its history: Against the background of the nuclear phase-out and ambitious climate protection goals, the share of renewable energies will be greatly expanded, and energy efficiency as well as energy conservation will be drastically increased. The Leibniz research network called "Energy Change", in which INP Greifswald is a partner, addresses questions of energy change in an interdisciplinary approach combining social science with natural sciences and engineering.

Leibniz Research Alliance on Sustainable Food Production and Healthy Nutrition

Securing food supply is one of the greatest global challenges of the 21st century. There is a quantitative as well as a qualitative dimension to it. 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. The alliance has skills in the natural sciences, engineering, economics and the social sciences and is experienced in scientific political consultancy.

Leibniz Research Alliance on Medical Engineering: Diagnosis, Monitoring and Therapy

A valuable and reasonable medical care is especially in regard to an ageing population an important challenge for our society and is therefore the focus of the Leibniz research alliance "Medical engineering: diagnosis, monitoring and therapy". Physicians, scientists and engineers work in close collaboration to ensure that the technical solution meets the requirements of the medical issue. Social scientists study questions of marketability and the social acceptance of these innovations.

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.

Legal Issues Group: 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 Legal Issues Working Group meets twice a year and is usually connected with the meetings of the Administrative Committee.

International Affairs Working Group: This Working Group was officially launched on 27 November 2013 in order to clarify strategic issues with respect to all international activities of institutes in the Leibniz Association. Accordingly, it is addressing dedicated advisors who are responsible for such matters. The International Affairs Working Group should clarify the strategic objectives of the Leibniz Association in the area of international matters and provide participants with information about forthcoming calls for proposals, projects and deadlines, and advise them on individual questions. The Working Group meetings take place about every six months.

Finance Working Group: This Working Group is an open group for administrative directors of different Leibniz institutes. It pursues the following goals:

- Sharing of best practice with respect to financially relevant topics
- Formulation of positioning to financially relevant issues
- Support of the Executive Board, Administrative Committee and Headquarters in financially related decisions
- Participation in trainings with financial topics

Press and Public Outreach Working Group: This Working Group helps to share experience on questions related to public relations and develops concepts and methods for the internal and external communication of the Leibniz Association.

Europe Working Group: This Working Group offers EU liaisons, external funding managers, research coordinators and scientists a platform for the exchange of experience on all aspects of EU application filing and project management. The experience accumulated in the working group constitutes the basis for opinions on the rules of the EU research funding programs. Furthermore, the Working Group is involved in sharing of information with the Brussels office.

Sustainability Working Group: The aim of this Working Group is to merge competencies and networking efforts among the Leibniz institutes by assessing consequences and evaluating sustainability of the institutes' activities. The "Working Group for Sustainability Impact Assessment (SIA)" is a permanent working group assessing political, social and scientific consequences of strategies and instruments and their sustainability. Findings are provided to policy-makers and contribute to the decision making process of policy makers.

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.
www.plasmashape.eu

Sonderforschungsbereich Transregio 24 (SFB-TR 24 // Collaborative Research Centre) „Fundamentals of Complex Plasmas“: Third funding period approved successfully

The Sonderforschungsbereich Transregio 24 (TRR24 // Collaborative Research Centre) called "Fundamentals of Complex Plasmas" is focused on non-thermal, low-temperature plasmas, whereby "complex" includes both the embedding of electrically charged microparticles that form a strongly linked subsystem and the presence of negative ions and reactive atoms and molecules in interaction with surfaces. The combination of the expertise of leading scientists at the Ernst Moritz Arndt University of Greifswald, the Christian Albrechts University of Kiel and INP Greifswald ensures TRR24 to be a strong collaboration in this field of plasma research.

In the third funding period (2013 - 2017), the participants in TRR24 are planning detailed studies on the new and important findings and developments from the second funding period, which will lead to a successful conclusion of the scientific objectives that were determined at the beginning of TRR24. For example, research will be done on crystallization dynamics, defect structure or wave phenomena in the transition from cluster to bulk material, furthermore on the role of negative ions in plasma or in plasma interface layer. This strategy will be accompanied by a strengthening of application-oriented research in the field of nanosciences and includes simulations and experiments on the production of metal-polymer composites, the growth of nanoparticles in the initial phase, the formation of particulates in atmospheric pressure discharges or experiments on the inclusion and dynamics of dust clouds in magnetized plasmas. The significant role of surface charges was identified as a new focus. The strategic objectives of the third funding period will stimulate the long-term development in this area of plasma research.
www.tr24.uni-greifswald.de

OGAPLAS: DFG/AIF Cluster „Optimization of gas utilization for atmospheric pressure plasma processes“

In the context of the research cluster OGAPLAS (OPTIMISATION OF GAS UTILIZATION FOR ATMOSPHERIC PRESSURE PLASMA PROCESSES), basic studies of various atmospheric pressure plasma processes (AP plasma processes) are performed to support the dissemination of this technology and to support associated market opportunities. The potential areas of application for AP plasma processes range from electronics to automotive manufacturing, photovoltaics and medicine.

Objectives
- Reduced gas consumption
- more efficient use of raw materials
- Development of methods for gas recycling

For the achievement of the objectives, it is necessary to have the cooperation of interdisciplinary scientists within the cluster in the areas of:
- Plasma physics and technology
- Surface technology
- Mechanical engineering
- Chemistry

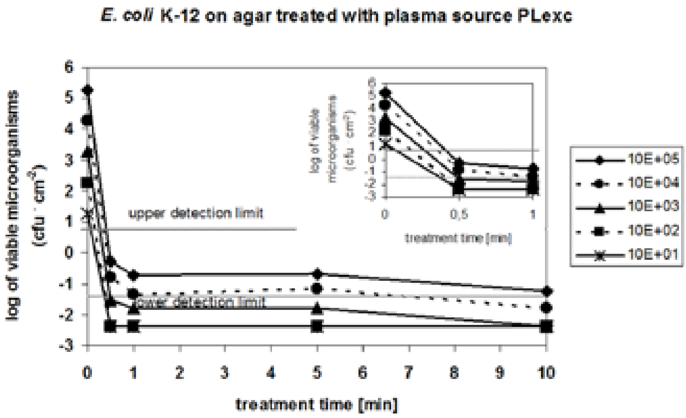
The project management of the AiF/DFG joint project is handled by Prof. Eckhard Beyer from the Institute for Production Engineering at the Technical University of Dresden (TUD). The project managers of the eight subprojects are experienced scientists who have already successfully run national and international projects.
AP plasmas are insufficiently used in industry to date, despite their high technological and economic potential and demonstrated successful implementations in production processes. The main reason is a lack of understanding of the complex processes in plasma with respect to disadvantages such as high gas consumption, insufficient precursor utilization and poor reproducibility. The optimization of the plasma sources and reactors that are used, are based on basic studies of plasma processes and fluid dynamics, and permit significantly improvements in the performance of this innovative technology - including resource efficiency. This approach is designed to provide the basis for a further dissemination of

AP technology in the areas of the glass industry, plastics, the steel industry, photovoltaics and biotechnology.
www.ogaplas.de

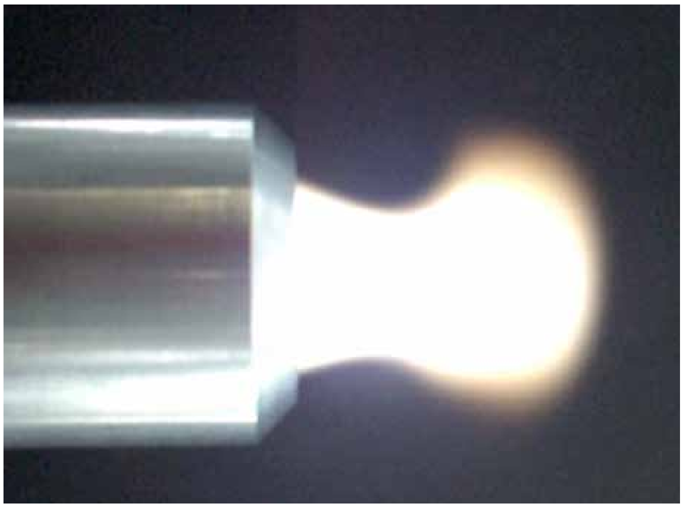
SafeFresh: Innovative monitoring and disinfection procedure for microbiological safety in the production chain for fresh foods of plant origin

Motivated by the EHEC epidemic in 2011 in Germany, the first investigations on the inactivation of disease-causing germs by means of plasma processes were carried out in the FriPlas project (BLE/BMELV). Promising results have led to the initiation of the SafeFresh project in the framework of the program Research for Civil Security.
The aim of the project SafeFresh is to generate the need-based and goal-oriented implementation of innovative disinfection procedures to deal with epidemics or terrorist attacks (food defense) through a novel form of monitoring.
Project partners include the Fraunhofer Institute for Process Engineering and Packaging (Fraunhofer-Institut für Verfahrenstechnik und Verpackung // IVV), the Leibniz Institute for Agricultural Engineering in Potsdam-Bornim (Leibniz-Institut für Agrartechnik Potsdam-Bornim e.V. // ATB), the company Löhrke GmbH and the company RIPAC-Labor GmbH. The associated partner is the company Gartenfrisch Jung GmbH. Subcontractors are neoplas GmbH, inter 3 GmbH and the FU Berlin - Institute for Microbiology and Animal Diseases. INP is developing the Plasma Processed Air (PPA) procedure as an innovative disinfection process. Examples of the applications are shown in the Figures.
www.safefresh-projekt.de

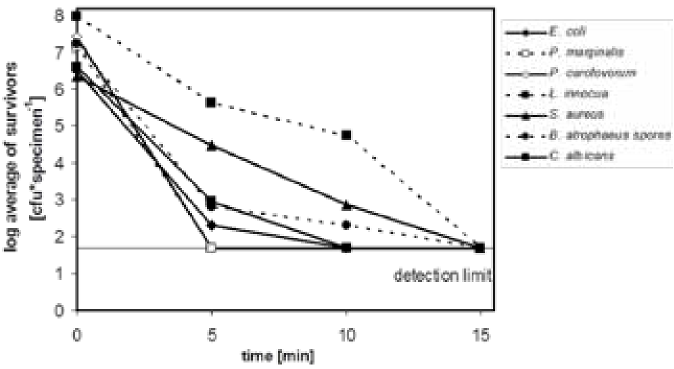
Treatment chamber for the Plasma Processed Air (PPA) procedure.



Inactivation kinetics for E. coli on agar plate with PPA procedure



Microwave-excited remote plasma torch PLexc



Inactivation kinetics for E. coli on apple with PPA procedure

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.

Campus PlasmaMed - Sub-projects at INP

Bundling and developing competencies in plasma medicine

Campus PlasmaMed was supported by the German Federal Ministry of Education and Research (BMBF). After the positive evaluation of the first funding period (2008-2010), the Campus was extended in January 2011 into the second phase, which ran until September 2013. A main objective of this research alliance of many renowned and accomplished research institutes, universities, hospitals and companies was to research most promising and safe applications of atmospheric-pressure plasmas in medicine. These studies were based on systematic and interdisciplinary basic research on the interaction of individual plasma components with living organisms.

The collaboration included following partners:

- Leibniz Institute for Plasma Research and Technology (INP Greifswald),
- Ernst Moritz Arndt University of Greifswald,
- University of Rostock,
- Stralsund University of Applied Sciences,
- Neubrandenburg University of Applied Sciences,
- Ferdinand Braun Institute, Leibniz Institute for High Frequency Technology, Berlin
- Charité – University Medicine Berlin,
- Unfallkrankenhaus Berlin (Accident Hospital Berlin),
- Forschungszentrum Wismar e. V. (Wismar Research Centre),
- HAWK – Hochschule für angewandte Wissenschaft und Kunst, Göttingen (University of Applied Sciences and Art) and
- Cinogy GmbH, Duderstadt

Figure: Campus PlasmaMed: Partners and Industry Advisory Board

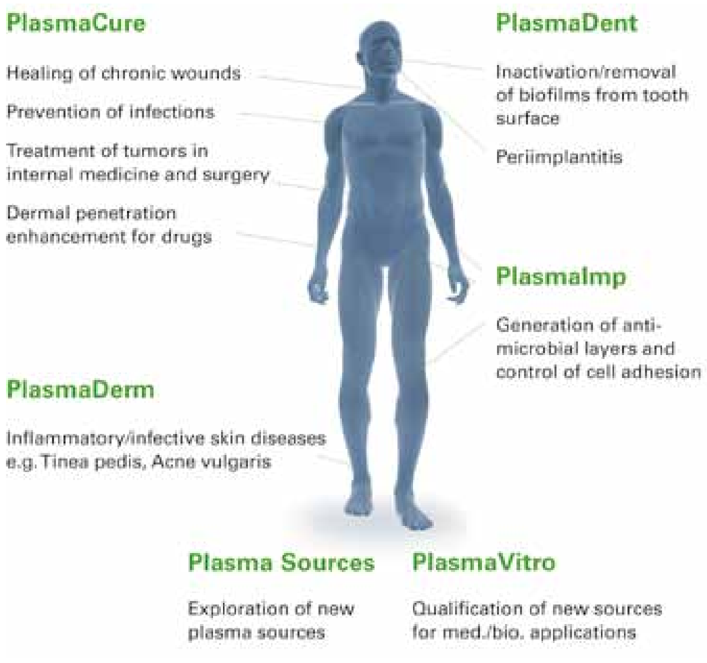


Figure: Thematic directions in the Campus PlasmaMed

The Campus was divided into six main thematic directions, each covering a specific aspect of plasma medicine. In addition to the four main topics, which are directed at various medical fields (PlasmaDerm for skin medicine, PlasmaDent for dentistry, PlasmaImp for implant medicine and PlasmaCure for wound healing), the two other main topics addressed the characterization of suitable plasma sources (Plasma Sources) as well as a detailed in-vitro study of biological plasma effects (PlasmaVitro).

A clinical study was successfully completed during the course of the project, and five laboratory prototypes and two certified medical devices were developed. The medical devices that received the first approval of a cold plasma instrument for wound healing in Germany included the kINPen MED®. In addition 148 scientific articles were published by the research alliance.

Two journals were founded by the Research Programme of Plasma Medicine. Campus PlasmaMed held the presidency of the International Society for Plasma Medicine and was the organizer of the 3rd International Conference on Plasma Medicine in 2010, which allowed for the combination of two independent conferences in the research field of Plasma Medicine.

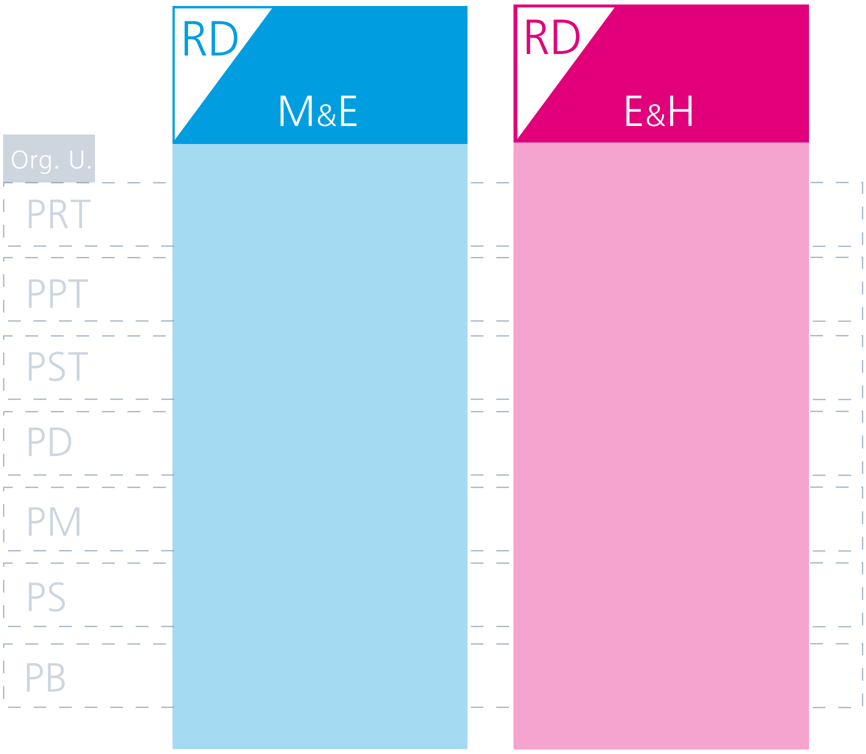
This initiative succeeded in getting the state of Mecklenburg-Western Pomerania and the Board of Trustees for the Healthcare Industry in Mecklenburg-Western Pomerania to recognize that plasma medicine is not only a topic of great interest, but also a unique selling point and thus a great opportunity for the state of Mecklenburg-Western Pomerania. The state-funded project within the framework of the invitation to tender for "Healthcare Industry Mecklenburg-Vorpommern" (Gesundheitswirtschaft MV) made it possible to back this up and anchor the focal point of Plasma Medicine in the 2020 Master Plan for the Healthcare Industry in Mecklenburg-Western Pomerania.

Another great success was the establishment of the world's first professorship for plasma medicine, which has been filled by Prof. Thomas von Woedtke.
Campus PlasmaMed engaged in successful strategic collaborations to establish an interdisciplinary, workable, overarching organization that let plasma medical research at INP to become one of the leading institutions – with the spin-off of the company neoplas tools GmbH – contributed to strengthening of the innovative potential of the region.

The sustainability of the project is ensured by approved follow-up projects (€ 2.4 million) in addition to pending applications (€ 4.7 million). Establishing the International Society for Plasma Medicine and the National Centre for Plasma Medicine allow to internationalize this field of research and to bring the most important research groups together that are active in the field of plasma medicine. In addition, new industrial cooperation partners were gained.

For the future, INP plans scientific projects in the area of dental medical applications and other clinical studies in the project "Plasma Medical Research – New Pharmaceutical and Medical Fields of Application". For example, in the joint research project "NormPlas", atmospheric pressure plasma sources for medical applications are standardized on the basis of obligatory general and application-based evaluation criteria. Other funded projects deal with the microbial decontamination of food and should feed into bilateral industrial projects.

www.campus-plasmamed.de



Matrix structure of the Research Divisions (RD) and Scientific Departments (Org. U.)

Research Divisions Plasmas for Materials & Energy

- Research Programme Surfaces / Thin Films
- Research Programme Catalytic Materials
- Research Programme Process Monitoring
- Research Programme Welding / Switching

Research Divisions Plasmas for Environment & Health

- Research Programme Bioactive Surfaces
- Research Programme Plasma Medicine / Decontamination
- Research Programme Pollutant Degradation
- Research Programme Bioelectrics

Scientific Departments

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

RESEARCH DIVISION

MATERIALS & ENERGY

Overview

This Research Division addresses subjects involving the production of functional surfaces, thin films and catalytic materials by using plasma processes accompanied by diagnostic techniques for process monitoring as well as topics in electric power engineering and process technology, particularly in the field of arcs. The combination of electrical engineering and plasma technology can be considered as the historical origin of gas discharge physics. A unique aspect of the Research Division's strategy is the systematic linking of sophisticated scientific plasma modelling with diagnostic methods of spatial and temporal high resolution. Experimental studies on application-relevant issues in the aforementioned topics are conducted in state of the art laboratories. The current focus of fundamental research carried out is directed to surface treatment using non-thermal plasmas and the interaction of thermal plasmas with the electrodes.

Research Programme Surfaces/Thin Films

- Fundamentals of functional films
- Plasma and optical technologies
- TRR24 "Fundamentals of complex plasmas", sub-project: Non-thermal, reactive atmospheric pressure plasma jet

Research Programme Catalytic Materials

- Fundamentals of catalyst modification
- Light2Hydrogen

Research Programme Process Monitoring

- Fundamentals of plasma chemistry
  – Plasma wall interaction in molecular plasmas
- Ultrasensitive optical detection of trace gases
- PECVD processes in silane-based plasmas

Research Programme Welding/Switching

- Fundamentals of electrical arcs
- Welding arcs
- Switching arcs
- Loss of the night

Introduction

Today, plasmas are an indispensable tool for the production of high-quality functional films and the key to innovative surfaces and novel products

Accordingly, the technological area of interest spans the range from tuning of interface properties, the modification of chemical-functional groups on the surface to the production of thin films and their structuring on a wide range of materials and geometries. The diverse and much sought-after applications rely on a number of process-related advantages of the plasma processes. Those 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.

The Research Programmeme already made fundamental contributions particularly in thin film deposition using non-thermal atmospheric pressure plasma and in the production of high-quality optical thin films using plasma-ion-assisted deposition. In both subject areas the findings relate to the fundamental characterization of the properties of the process plasma, with partially newly developed diagnostic techniques and the active control of the thin film deposition process.

In the atmospheric pressure range, progress was achieved in the local deposition of functional films on the basis of silicon-organic compounds films by means of non-thermal miniaturized plasma jets and in the experimental characterization of these plasmas.
For this purpose, a diagnostic method, laser-schlieren deflectometry, was described for the first time and successfully used to determine the temperature profile in the effluent of the micro-discharge.

Progress has been achieved in the simulation of fluid dynamics and kinetics in the single discharge filament that represent significant contributions to understanding the discharge mechanisms.

Other essential works in the area of atmospheric pressure plasmas are related to optimize the supply of reactive raw materials and to reduce the gas consumption. Hence, they contribute to an improved sustainability of atmospheric pressure processes in surface technology.

In the low pressure area, the focus is on plasma processes to produce high-value optical films by using plasma-ion-assisted deposition (PIAD). PIAD represents a well-proven method for 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. The plasma of the PIAD process has been characterized at an unrivalled degree of complexity. The space-dependent plasma parameters for electron and ion components along with the energy and particle fluxes to the growing film could be quantified. These efforts led to an improved method for control of thin film growth by an active process control. Implemented for the first time, this novel process control obtains its control signals from variables derived directly from plasma parameters. Considerable improvement in reproducibility and the transferability to other devices have been demonstrated

Application potential

Functional coatings with plasma CVD
- Increased scratch resistance
- Control of the gas permeability
- Corrosion protection

Optical films by PVD and ion-beam-assisted plasma processes
- Oxide films
- Optical filters
- 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 (plastics, CFK, GFK, metals)

Contact

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Fundamentals of functional films (core-funded project)

Problem

The plasma-assisted deposition of high-quality functional films requires the knowledge and systematic utilization of the processes evolving in these plasmas in order to achieve a controlled formation of the aspired chemical film structure at molecular level. This is considered the only way to consistently achieve well-defined coatings with the desired properties.

An existing change in the chemical structure of the condensing film in lateral direction is often problematic with films produced by means of PE-CVD processes under atmospheric pressure (PE-CVD: plasma-enhanced chemical vapour deposition). This can lead to an unintentional increase in the spatial inhomogeneity and thus to impaired quality (density, pin-holes, refractive index).

Problem-solving approach

PE-CVD processes under atmospheric pressure conditions are investigated for the production of SiOx films. This research is conducted using non-thermal, miniaturized jet plasmas having been adapted to film deposition. The plasmas are 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. For the first time, besides the already proven organo-silicon raw materials, so-called spherosiloxanes are also studied, offering the potential to produce films with a complex, spatially regular molecular arrangement.

The detection of the controlled chemical composition takes place by the combining several complementary surface analytics methods.

Technological benefits

The obtained results offer the potential to produce functional films under atmospheric pressure in a previously unknown quality with respect to lateral homogeneity and a controllable chemical composition so that applications such as passivation film systems for complex (3D) components (such as sensors) and applications as permeation barriers or in corrosion protection become possible. Nanostructured films are relevant as surfaces for the heterogeneous catalysis.

Other aspects required by the industry include the improvement of the energy efficiency, the reduction of material usage and a reduction of the investment costs as well as the increase of the deposition rate.

Results in 2012/13

The reactive processes during thin film formation with the plasma jet were the object of both, experimental studies and simulations in fluid-dynamics. A discharge model was proposed, which permitted a combined description of the plasma formation, gas dynamics and thin film formation. This revealed the relation between plasma analytics, the resulting thin film properties and the process parameters. Ultimately, the spatial film homogeneity and the controllability of the chemical composition could be improved, as demonstrated for example for the carbon content of SiO_x films.

For the first time, the formation of nanostructured SiOx films based on TTMSS (Tetrakis(trimethylsilyloxy)silane) under atmospheric pressure was demonstrated.

Also for the first time, laser-schlieren deflectometry was applied locally to these jet plasmas in order to determine their temperature profile.

Plans for 2014

- Systematic investigation of the deposition of films under atmospheric pressure with spherosiloxanes and their film structure
- Experimental investigation on the temperature field of a non-thermal jet plasma
- Deposition of a-C:H:X films in low pressure (X=Si, F)

Contact

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Project partners:
University of Brno

Plasma and optical technologies (third-party funded project)

Problem

Plasma-ion-assisted electron beam deposition (PIAD) represents a well-proven method to produce high-quality components for thin film optics such as filters or dielectric mirrors in laser applications, telecommunications or measurement technology. However, the requirements placed on the reproducibility of the film characteristics (refraction index, absorption, film thickness) in the per-thousand range are no longer to be fulfilled for complex film systems with a conventional, empirical approach. The in-situ monitoring of processes is currently limited to the determination of the optical thickness. At present, the flux of plasma species to the growing film and their energy is not specified.

Problem-solving approach

The sub-project of the joint project "Plasma and Optical Technologies" (PluTO), which is funded by the German Federal Ministry of Education and Research (BMBF), is dedicated to the quantitative measurement of plasma parameters in a PIAD industrial coater with magnetic field supported hot cathode DC glow discharge as plasma source. The properties of the volume plasma and the fluxes to the substrate are characterized experimentally. As a result, quantitative information on the plasma is obtained for reference processes (single layers TiO_2, SiO_2, Al_2O_3 and MgF_2) for the first time and is correlated to the resulting film properties.

Technological benefits

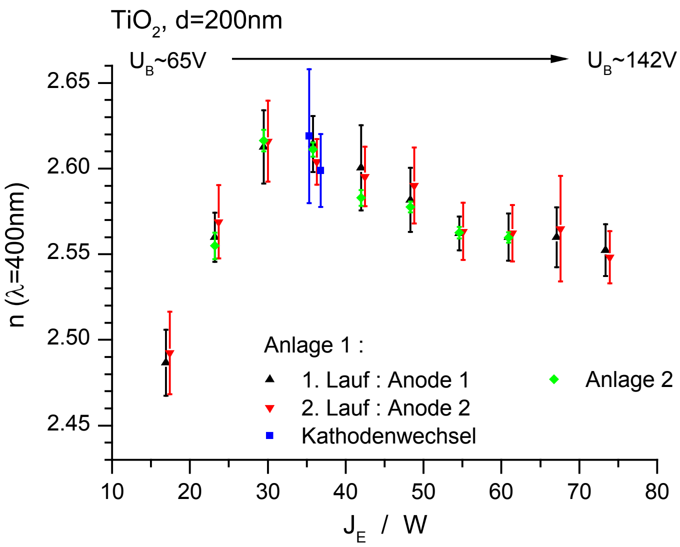
By characterizing the process plasma a new level of quality in the control algorithms is achieved. Whereas formerly a control had been based usually on electrical system parameters, now as control parameter the plasma characteristics that are actually relevant for film growth become accessible. Hence, industrial demands regarding e.g. reproducibility, spatial uniformity, improved energy efficiency and enhanced deposition rates without sacrificing quality are met.

Results in 2012/13

The formation of the ion beam is based on a plasma expansion from the source region into the recipient. The ion energy distribution that is critical for the support of the film growth is essentially determined by the control parameters of the plasma source, which is subject to drifts on account of the state of the electrodes.

The assumption of a non-local electron energy distribution on account of the low pressure (p~20mPa) could be verified experimentally. Furthermore, it was shown that conventional control procedures for the source can lead to a variation of the momentum and energy flux from the plasma towards the film surface, expressed by the ion beam power, up to a factor of 2. From the characterization of the plasma, a non-linear relationship between the source parameters and the ion beam power was derived and used for the implementation of a new control algorithm. By actively compensating for the drifts of the source this approach achieves a high degree of reproducibility. The transferability to other coating systems has been demonstrated, which qualifies the algorithm directly for industrial use.

TiO_2 film on Si wafer produced by the PIAD process for measurement purposes



Reproducibility despite dissimilar system status and for two different devices as demonstrated by the variation of the refractive index for TiO_2 depending on the ion beam power

Plans for 2014

- The end of the period will be in April 2014.
- Writing final report
- Planning of an industry-led follow-up project

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Sponsor:
German Federal Ministry of Education and Research (BMBF)

Non-thermal, reactive atmospheric pressure plasma jet

(sub-project of TR24 “Fundamentals of Complex Plasmas”)

Problem

Plasmas at atmospheric pressure are characterized by an increased collision rate, UV radiation by broadband continua and the formation of radicals by collisions with neutrals. With regard to their spatiotemporal behaviour, they are classified as highly non-stationary plasmas that appear both erratic and periodically structured. For their description, in addition to diffusion, also convection and flow processes have to be considered. There is very little knowledge about the active plasma components relevant for surface treatment processes under atmospheric pressure, such as functionalization or film deposition.

Problem-solving approach

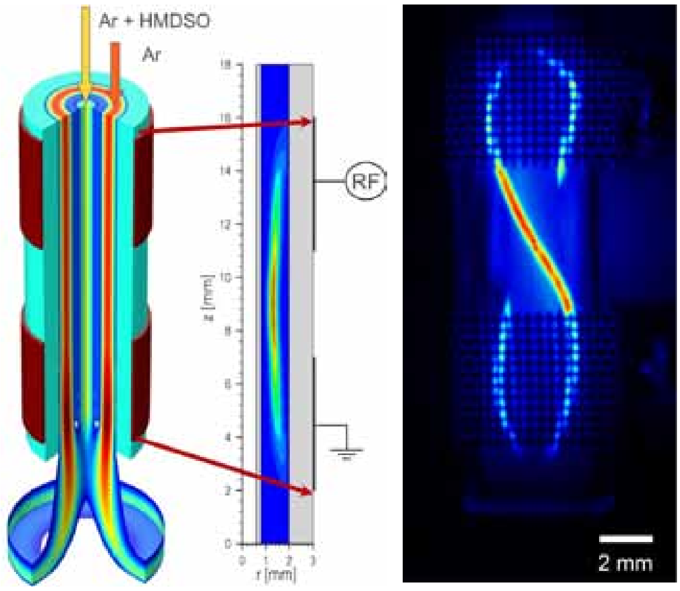
In the sub-project of the Sonderforschungsbereich (Collaborative Research Centre) Transregio 24 (TRR24) “Fundamentals of Complex Plasmas”, the plasma properties of a non-thermal plasma jet operating under atmospheric pressure are characterized experimentally by using spectroscopic methods, described by hydrodynamic modelling and considered in relation to the properties of deposited SiO_2 films.

Technological benefits

Discharge regimes are identified, leading to a film production process which is characterized by improved controllability of the properties of silicon-based film properties. Such films are used e.g. for adhesion promotion agents, permeation barriers or as corrosion protective film. The atmospheric pressure process offers potential savings in terms of the investment costs and the local treatment of large areas.

Results in 2012/13

The dynamic behaviour of a discharge filament could be recorded by phase-resolved emission spectroscopy. The quasi-stationary conditions present in this case are attributed to the excitation of metastable argon atoms, whose lifetime exceeds that of the HF period (27.12 MHz).
In the effluent of the plasma jet the temperature profile could be measured by the method of laser-schlieren deflectometry, newly established at INP. For the characterization of the discharge in the individual filament, a self-consistent, spatially two-dimensional model was established that includes a description of the filament contraction. The calculated electron densities agree well with experimental values.



Model of the plasma jet (left), calculated current density of an individual filament (centre) and optical emission of 2 single filaments rotating azimuthally at 107 Hz. Measured at a fixed phase of the HF excitation (27.12 MHz) (right)

Plans for 2014

- Analysis of kinetic processes and parameters in reactive jet plasmas for film deposition with silicon-organic raw materials
- Establishment of a global model for the description of the PE-CVD of SiO_2 films

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Introduction

Plasma technology has great potential for the production of catalytically active materials. Suitable technologies are especially necessary for the equipping of system components for the use of renewable energy sources with catalyst layers in order to gain widespread use.

Of particular interest are the production of catalysts for fuel cells, photochemical water splitting, the connection of photosensitizers or catalysts to electrically conductive or semiconducting materials, the deposition of semiconductor materials and photosensitive films for photovoltaic cells.

The electrochemical conversions of hydrogen and oxygen to water, as well as the reverse reaction, are currently the greatest scientific challenges for the efficient and sustainable production and storage of energy. Technologies such as the proton exchange membrane fuel cell (PEMFC) represent highly efficient and environmentally friendly energy processes. The optimization of the nanostructure of precious metal catalysts for the cathode side of the fuel cells, and an increase in the long-term stability makes a substantial contribution to the efficiency of generating electricity from hydrogen.

INP has developed and studied processes for the deposition of special titanium dioxide films in recent years. These coatings represent a model system and form the basis for the development of structures for the light-driven and thus renewable production of hydrogen. However, in order to market systems usable in practice with the levels of efficiency known in photovoltaic and a service life of up to ten years, new semiconductor systems are necessary. These must be additionally linked to other photoactive components known from the chemical catalysis. For successful implementation, however, technologies are required that – similar to those in photovoltaic (e.g. thin film solar cells) – ensure reliable, economically justifiable mass production methods. Here we view plasma technology to be in a key position.

Application potential

Customized properties for nano- and micro-particles
- Additives for paints/inks
- Additives for cosmetic products
- Adhesion promotion in composite materials
- For controlling active ingredient release in pharmaceutical compositions

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
- Quantum dots for photovoltaic
- Gold and silver nanoparticles for plasmon resonance-enhanced hydrogen production
- Precious metal films for the anodic oxidation of $NaBH_4$
- Nanostructured precious metal catalysts
- Electroactive metal polymer films

Surface modification
- Corrosion protection
- Adsorption capacity of adsorbers
- Control of the wettability

Diagnostic tools
- Thermal probe for the optimization of plasma processes and process management
- Microprobes in plasma (electrical, thermal, chemical)

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Fundamentals of catalyst modification (core-funded project)

Problem

Nanometer-sized semiconductors have unique properties due to quantum limitations, that make them interesting for pharmaceutical, biological and various physical applications such as photovoltaic. For technological use on a large scale, on one hand a higher throughput must be ensured, with a minimal amount of risky raw materials on the other hand. The two standard procedures for the production of nanocrystals each lack one of these criteria at the present time. Epitaxy has very low throughput, while wet-chemical processes work with raw materials that are often harmful to health and harmful to the environment, so additional waste management is necessary and higher safety standards apply.

Problem-solving approach

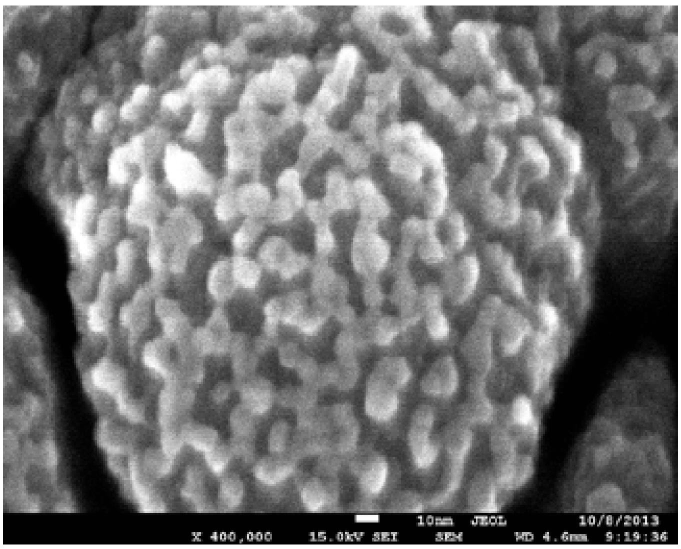
There are plasma-based methods to deal with these limitations, which are industry-tested and guarantee a high rate of throughput, and use non-toxic raw materials in a closed circuit. The application of PVD (physical vapour deposition) will allow for the deposition of photoactive nanocrystals on titanium dioxide films in order to demonstrate the feasibility of this new approach and to show the dependencies of the process parameters for the efficiency of light absorption and power generation.

Technological benefits

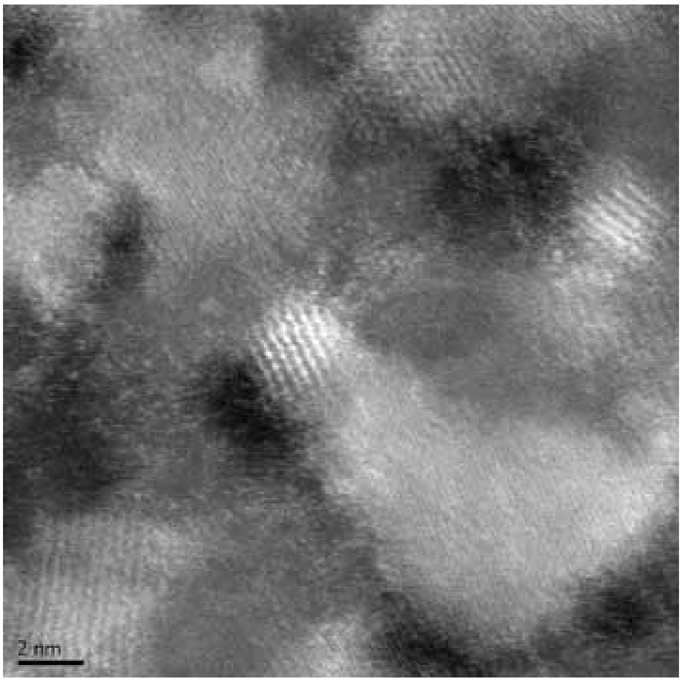
Climate change requires the transition from the fossil fuel energy towards renewable energy sources. This is further reinforced by the rising prices in crude oil and natural gas sectors. Photovoltaic offer a new inexhaustible source of energy, which must be used as efficiently as possible. The third-generation of nanocrystal-based solar cells meets the theoretical prerequisite of superseding the existing silicon-based cells in terms of efficiency and thus ensuring the future supply of energy.

Results in 2012/13

For the reactive plasma-based production of lead sulphide (PbS) nanocrystals, a plasma reactor was developed in which lead can be sputtered in a H2S reactive gas. They were deposited onto titanium dioxide, which was previously also produced in a reactive plasma process. It could be demonstrated that nanocrystalline particles are formed and that they consist to a greater extend of PbS. The photo-activity of the films could be demonstrated. An improvement of the particle distribution could be achieved with a subsequent calcination:



TEM photo of PBS nanocrystals.



SEM photo of PBS on TiO_2

Plans for 2014

- Improvement of the crystallinity efficiency
- Production of polythiophene films for the encapsulation of crystals.

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Light2Hydrogen (L2H // third-party funded project)

Problem

Hydrogen is one of the main carriers of energy carriers of the future. But it can only be used meaningfully for sustainable energy storage if it is generated from renewable energy sources, such as solar or wind, on an industrial scale. Even though there are a number of different solar-to-hydrogen concepts, these are usually inefficient and expensive, so that over 95% of the global production of hydrogen is still made from natural gas at the present time. Photo-electrochemical catalysis (PEC) allows for the production of hydrogen from water in one step. The theoretically high efficiency of the process is limited by the currently available materials, since they exhibit low activity in the visible range of the solar spectrum and are unstable under the ambient conditions of water-splitting. Currently, popular synthetic processes are complex and difficult to reproduce, which is why they are not suitable for industrial production. The L2H project challenges the INP to develop highly efficient catalyst films for the visible range by using processes that can be easily implemented in industry.

Problem-solving approach

The project work on new catalytic materials is closely linked to the project partner LIKAT. Accordingly, the LIKAT-synthesized high-efficiency water reduction and oxidation catalysts are fixed at the INP on nanostructured semiconductor thin films by plasma-polymerized allylamine (PAAM) encapsulation in order to achieve high long-term stability for the catalysts. In 2013, the focus was mainly on the optimization of the thickness of the polymer encapsulation and the development of TiO_2 semiconductor film as a substrate for the LIKAT dyes. The INP also concentrated on the development of plasma-assisted processes for the production of semiconductor films that are effective in the visible solar range such as WO_3 and C_3N_4.

Technological benefits

The nanostructured INP-coating systems are initially applicable as efficient and stable new photocatalysts for the newly-emerging technological field of solar water-splitting, in particular for multi-layer stacks of catalytic materials. Other fields of application, some of which have also already penetrated the market, are dye-sensitized solar cells as well as photocatalytic wastewater and air purification.

Scientific results in 2012/13

In addition to the successful results in the long-term stability of PAAM-encapsulated LIKAT dye/TiO_2 powder catalysts last year, now also a significant increase in photoefficiency in the visible range has been achieved (Figure 1).

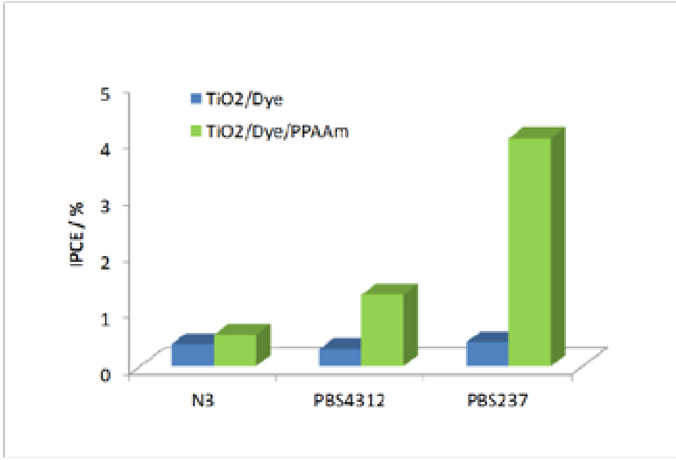

Figure 1: Photoefficiency of LIKAT-FS/TiO_2 catalyst structures with and without INP- plasma polymer encapsulation (λ = 430 nm).

The PVD process for WO_3 semiconductor films was successfully developed at room temperature initially, whereby a subsequent tempering step was necessary. Subsequently, the PVD process was conducted at higher temperatures (200-500°C) and the sputter performance was optimized. The film homogeneity, however, is still not satisfactory and is currently being optimized. C_3N_4 films could not be successfully produced by means of the current PVD process. Instead, there were N- doped carbon films with a high graphene proportion, which exhibited attractive photocatalytic activity, in particular at low film thicknesses. The film homogeneity and stability in aqueous electrolytes must still be optimized.

Plans for 2014

- Optimization of the PVD process for WO_3, particularly with regard to possible application as a photoanode in the L2H PEC prototype (LIKAT)
- Optimization of the PVD process for the deposition of photocatalytic CN films.
- Development of a PVD process for the C-doped or N-doped WO_3 films.
- Production of TiO_2 and WO_3 films for L2H project partners.
- PPAAm encapsulation of dye-sensitized TiO_2 films and N-doped graphene films

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Subcontractors:
balticFuelCells GmbH, neoplas GmbH, Wasserstofftechnologie-Initiative Mecklenburg-Vorpommern e.V.

Introduction

The Research Programmeme Process Monitoring is focused on the investigation of (i) fundamental phenomena and of (ii) the technological potential of interaction processes between plasmas and surfaces. These studies are based on the application of highly sensitive diagnostic methods, which are in particular suited for the analysis of molecular plasmas. Effective and sustainable use of resources, the degradation of hazardous substances and an efficient use of energy are in the centre of interest. An important scientific focus is the improved understanding of chemical phenomena in molecular plasmas, particularly the kinetics of transient molecules. The influence of surface properties on plasma processes becomes increasingly important, whereby the transition from low pressure to atmospheric pressure plasmas is systematically performed.

The present work, carried out in international scientific cooperation, has tremendous relevance not only for the plasma-assisted destruction of harmful gases such as volatile organic compounds (VOCs), but also for the monitoring of technological plasmas as well as for process controlling in industry. In addition, plasma diagnostic methods are continuously developed, which are advantageous to study, e.g., plasma-assisted deposition and etching processes, but which also have a potential to be used in medicine, for security systems, and for environmental monitoring.

Application potential

Investigating the role of plasma-stimulated solid surfaces

- Plasma-catalytic pollution abatement
  Plasma-assisted surface treatment
- Optimization of atmospheric pressure discharges

Analysis of the chemical behaviour of higher molecular species in plasmas and gases

- Plasma technology (e.g. plasma etching in the semiconductor industry, deposition of Si-based films in the solar industry)
- Workplace and environmental monitoring
- Breath gas analytics
- Safety aspects

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

Problem

The plasma-assisted abatement of pollutants at atmospheric pressure is an alternative to conventional destruction methods. However, formations of unwanted by-products, as well as the insufficient selectivity of reaction pathways, are general problems preventing further successful development of this technology. An improvement in the degradation of pollutants, in particular a reduced amount of unwanted by-products, could be achieved using a combination of serially arranged reactor units. However, the main physical and chemical processes in multi-stage reactors are far from being understood.

Problem-solving approach

Recently, dielectric packed-bed plasma reactors working at atmospheric pressure have proven to be a promising approach particularly for the plasma-assisted destruction of volatile organic compounds (VOCs). However, the production of unwanted by-products, such as formaldehyde, in particular, remains an unsolved problem. The development of multi-stage reactors is a novel approach that not only ensures the almost complete and energy-efficient abatement of the relevant VOCs but also has the potential for a significant decrease in the production of by-products. The study and optimization of these novel systems, in particular of the plasma-wall interactions that have become increasingly significant, require both a gas supply of high reproducibility and a highly-sensitive, quantitative multi-component diagnostic unit as such as a Fourier Transform Infrared Spectrometer (FTIR). Figure 1 shows the basic structure of the multi-stage reactor with a gas supply and the analysis unit of the abatement of pollutants [1].

Technological benefits

The understanding of optimized dielectric packed-bed plasma material reactors, particularly in their multi-stage design, has the potential to open up new approaches to plasma-based substance conversion that are focused on the systematic production of reactive species such as vibrational excited nitrogen and ozone. The present study improves the understanding of the underlying phenomena of plasma-wall interactions.

Results in 2012/13

The plasma chemical destruction of ethylene, C_2H_4, as a model substance, could be widely understood on the basis of the monitoring of ten stable reaction products. The use of a multi-stage dielectric packed-bed plasma reactor has led to a significant reduction of the amount of unwanted by-products, such as formaldehyde, CH_2O, and formic acid, CH_2O_2 [1]. This new result can be seen in Figure 2.

Plans for 2014

- Analysis of the time dependence of the plasma-wall interaction processes by studying surface absorptions at interfaces
- Clarification of the role of select transient plasma components on the main paths of plasma-chemical processes
- Further development of laser-based diagnostic methods for multi-component detection

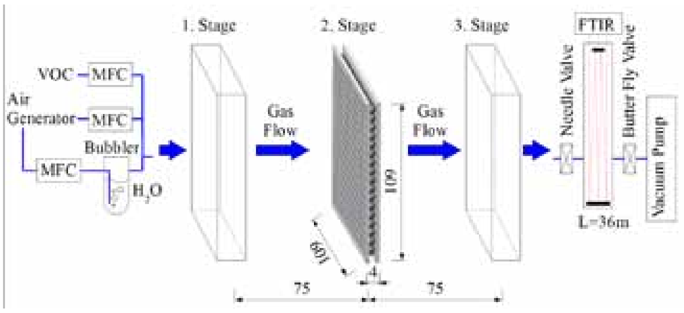

Figure 1: Basic structure of a multi-stage reactor for the degradation of pollutants with gas supply and analysis unit [1].

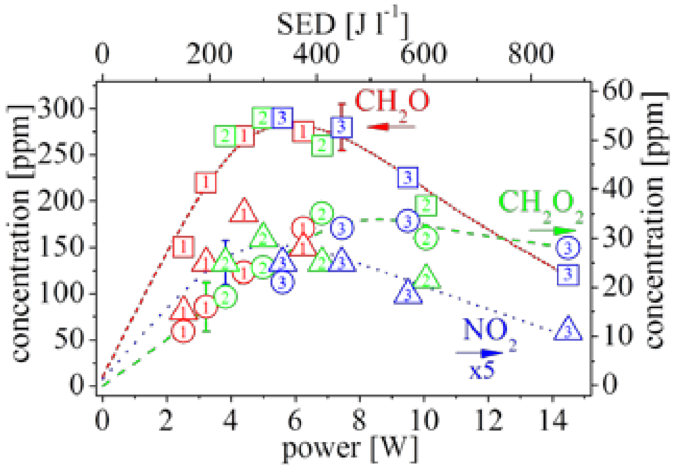

Figure 2: The production of CH_2O, CH_2O_2 and NO_2 during the destruction of C_2H_4 as a function of the power and the specific energy [1].

[1] M. Hübner, O. Guaitella, A. Rousseau, and J. Röpcke. 2013 J. Appl. Phys. 114 033301

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Ultrasensitive optical detection of trace gases (BMBF-VIP // third-party funded project)

Problem

For the development, optimization and control of technological processes, for monitoring of harmful emissions, in medical breath gas analysis, as well as for the detection of drugs and explosives, the analysis of trace gases has become highly significant. Classical detection methods are faced with problems of long measurement times, possible ambiguities, often too high detection limits and interference effects.

Problem-solving approach

Problem-solving approach
The method of optical absorption spectroscopy is free of such disadvantages if it is designed properly. At the INP Greifswald in 2008, a prove-of-principle experiment in the field of trace gas detection was carried out on the basis of so-called Cavity Enhanced Absorption Spectroscopy (CEAS). This method uses an optical resonator that is formed by a cavity between two highly reflective mirrors. For the first time, a very compact structure of the spectrometer was achieved at the INP Greifswald. It combined a CEAS measuring cell that had a very long optical path for the achievement of a very low detection limit and an extremely low volume to ensure a short gas replacement time, with a quantum cascade laser working at room temperature and emitting in the mid-infrared spectral [1].

Technological benefits

The project validates the industrial potential of the CEAS technology and verifies the possibility of using this technology as a basis for the development of compact and robust sensors that are capable of detecting trace gases in situ and online with a detection limit in the sub-ppb range.

Results in 2012/13

A very sensitive EC-QCL-CEAS spectrometer was set up with an absorption length of 1780 m with an optical measuring cell length of just 32 cm. The performance of this compact system was demonstrated at the detection of traces of methane [2].

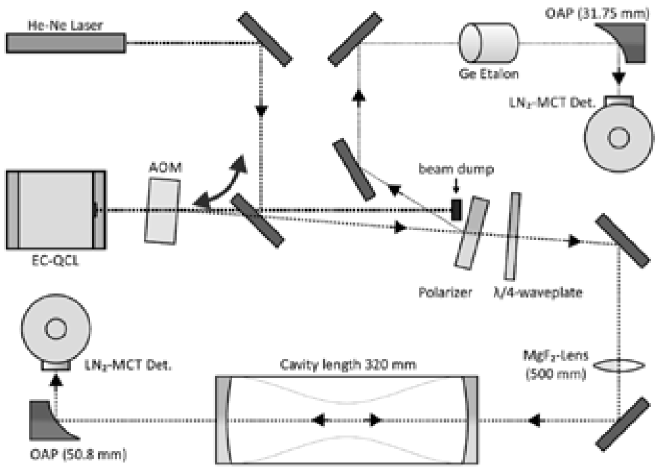

Figure 1: Schematic structure of the EC-QCL-CEAS spectrometer for trace gas detection [2].

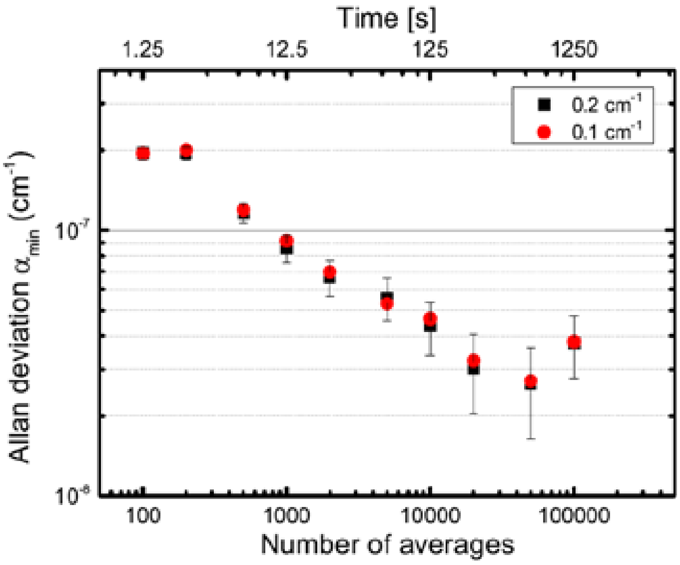

Figure 2: Allan plot of the noise-equivalent absorption in the trace gas measurement of methane [2]

[1] S. Welzel, G. Lombardi, P.B. Davies, R. Engeln, D.C. Schram, and J. Röpcke 2008 J. Appl. Phys. 104 093115
[2] J. H. van Helden, N. Lang, U. Macherius, H. Zimmermann, and J. Röpcke 2013 Appl. Phys. Lett. 103 131114

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German Federal Ministry of Education and Research (BMBF)

PECVD processes in silane plasmas (industrial project)

Problem

For the production of solar cells, silicon films are deposited by PECVD processes in silane plasmas. Nowadays, thin-film technology has made it possible to achieve the best efficiency with the so-called tandem solar cells. However, the effective production of the amorphous (a-Si:H) and microcrystalline (µc-Si:H) silicone films is still a challenge. For further optimization of the industrial production process as well as for a better effectiveness of such solar cells, a detailed understanding of the plasma chemical phenomena is required. The currently used diagnostic methods are not well suited for the quantitative monitoring of industrial deposition processes in the plasma-technology-relevant pressure ranges.

Problem-solving approach

Quantum cascade laser absorption spectroscopy (QCLAS) has the potential to quantitatively record molecule concentrations in a very sensitive manner, in-situ and time-resolved [1]. The INP has worked in close cooperation with the project partner Oerlikon Solar in Trübbach (Switzerland) to develop a QCLAS design that would allow the monitoring of absolute silane concentrations under industrial deposition conditions. The aim was to quantitatively monitor the fragmentation behaviour of the silane precursor in relation to the plasma parameters.

Technological benefits

Knowledge of the fragmentation behaviour of silane allows the optimization of plasma-chemical processes that lead to the deposition of a-Si:H and µc-Si:H silicon films. The experimental access supports existing simulations and thus facilitates the evaluation of process scaling for cost-effective, highly efficient thin film solar cell modules.

Results in 2012/13

Quantitative concentration monitoring of silane made it possible to achieve experimental access to the dissociation behaviour of the precursor for two different deposition regimes (a-Si:H and µc-Si:H films). The derived fragmentation efficiencies provided the first experimental basis for the evaluation of the deposition process.

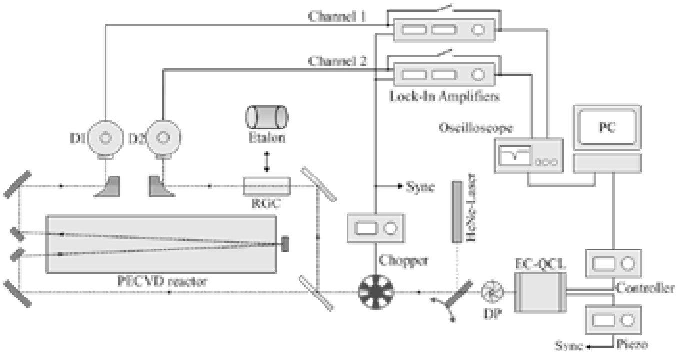

Figure 1: Schematic structure of the EC-QCL spectrometer for monitoring silane-containing PECVD processes [2].

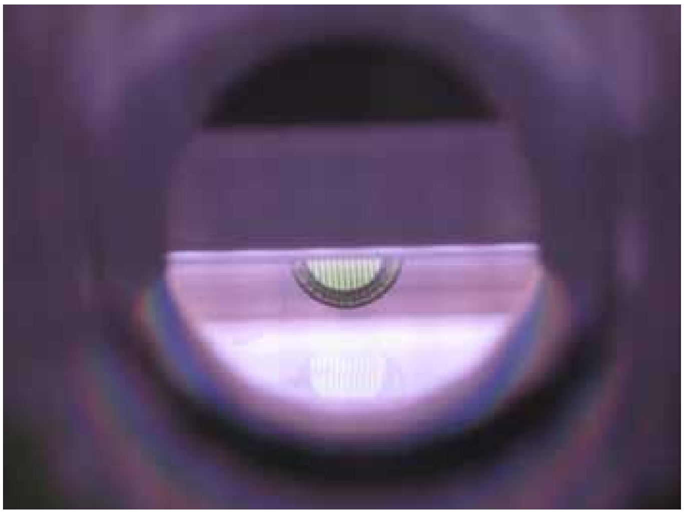

Figure 2: View of the industrial PECVD reactor with optical access for the EC-QCL spectrometer.

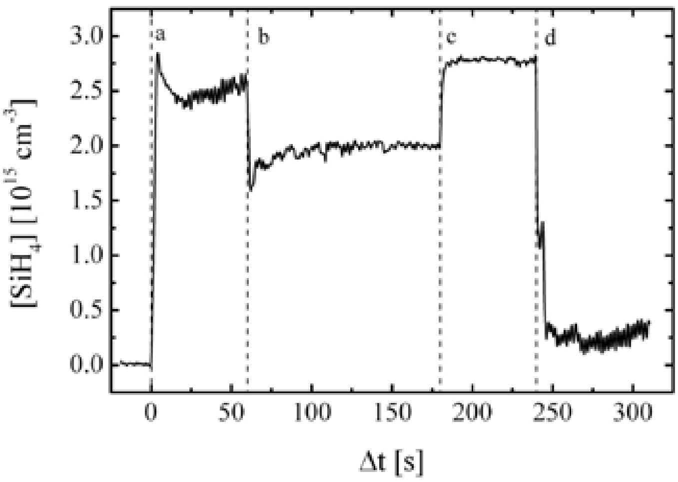

Figure 3: Monitoring of the silane concentration during a PECVD process for the deposition of a-Si:H films [2]. Gas inlet in phase a, plasma during phases b-c and pumping from phase d.

[1] S. Welzel, F. Hempel, M. Hübner, N. Lang, P. B. Davies and J. Röpcke. 2010 Sensors 10 6861.
[2] N. Lang, S. Hamann, A. Salabas, and J. Röpcke, FLTPD 2013, Rolduc, The Netherlands, Conf. Proc.

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Introduction

The Research Programmeme Welding/Switching is dedicated to studies of thermal plasmas and their technological applications. Experimental and theoretical research work focuses on the application of arc plasmas in switchgears of high, medium and low voltage technology and in various production techniques such as arc welding, plasma hybrid welding and plasma cutting. Furthermore, the existing expertise in the diagnosis and characterization of the plasma light sources is being continued in studies on the biological aspects of lighting effects.

The understanding of the basic physical mechanisms of the arc and its mechanisms relevant for operation in various applications form the core of the Research Programmeme. More detailed knowledge of the properties and dynamics of the arc and their control mechanisms allow the derivation of new approaches to process and method improvement. For this purpose, in particular optical diagnostics are specified and appropriate evaluation methods are developed. The studies are carried out on both model systems as well as the real process. The experimental diagnostics are accompanied by appropriate simulation and modelling. Appropriate models of the arc or its subdivisions as well as complex procedures for the simulation of arc applications are being developed. Numerical simulation helps to significantly reduce the development times of devices and sources.

The research programme primarily concentrates on plasma applications, which possess significant potential for the saving of energy and the safe distribution of energy due to their energy use and/or their range of application. In addition to improvements of the performance characteristics, including energy efficiency, process safety and lifetime of the systems, additional criteria are increasingly being investigated such as environmental impact and avoidance of health-damaging effects. Accordingly, for example, it is required to reduce harmful emissions in arc applications. Future studies in the field of light sources will be dedicated to the aspects of health and human well-being that play, for instance, a special role in the case of night work.

Application potential

The research methods for process improvement and the implementation of new approaches developed in the Research Programmeme can be used in many plasma-based technologies in production and process technology. Examples are

- ..arc welding processes
- ..plasma welding processes
- ..plasma hybrid welding processes
- ..plasma torch for cutting
- ..torch for plasma spray technology
- ..torch for plasma-assisted vapour deposition

In electrical power engineering, the effective energy dissipation of arcs is exploited in switchgears. The simulation and diagnostics of the arc supports

- device development on circuit breakers in low- voltage and high-voltage technology
- development of approaches for new extinguishing principles

Experiences in the study of plasma light sources support the development of radiation sources for general lighting and special applications, taking into account the biological effect on

- ecosystems
- human health
- safety by influencing the human factor

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Fundamentals of arcs (core-funded project)

Problem

Thermal plasmas are the essential component in energy supply applications, particularly for switchgears in low, medium and high-voltage technology, as well as in many areas of process engineering, including arc welding, plasma, and hybrid welding and for plasma cutting. Despite established technologies and many years of research work, the knowledge about the properties and working mechanisms of the arc continue to be inadequate. This hinders technological innovations based on knowledge of the physical processes. The aim is increasingly to use models and simulations for device and process development. They must be developed and validated in experiments with sufficient detailed knowledge about the processes in the plasma and on the interaction with surfaces.

Problem-solving approach

A strengthening of the coupling between modelling and experiment is carried out by the construction and commissioning of the arc laboratory, which allows for detailed experiments using optical diagnostics on switching arcs. A deepening of the work on non-equilibrium models, particularly for describing the plasma near interfaces and taking into account plasma-chemical reactions, leads to the development of efficient realistic simulation instruments that can be used for design and parameter optimization.

The existing optical diagnostics to determine the temperatures and species densities, as well as many other relevant properties in arcs, are used for the analysis of the plasma, including time-varying processes, and for the analysis of radiant surfaces such as electrodes and melting.

Technological benefits

Qualitative measurements and experimentally validated models increase the understanding of the physical processes and generate concepts for optimized or novel process management. Simulations reduce the expenses for the design and development of the systems.

Scientific Results in 2012/13

The studies were carried out on a wide range of topics that produced, inter alia, the following results:

- Development of a new MHD model, taking into account the plasma electrode interaction, deviations from thermal, chemical and ionisation balance for freely burning arcs in argon
- Development of methods for time-resolved and spatially-resolved determination of temperature in arc plasmas based on high speed cinematography in combination with narrow-band optical filters (in cooperation with UniBw Munich)
- Preparation of models for emissivity and of methods for determining the surface temperature of molten surfaces in welding processes by using high-speed cinematography

Plans for 2014

Arc diagnostics will be further developed in order to better record the spatial structures and temporal dynamics in the plasma as well as the processes on the surfaces. The experimental basis for the investigation of high current arcs is being expanded. Developing models for thermal plasmas with deviations from the equilibrium continues with regard to the special aspect of melting electrodes.

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Project partners:
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Welding arcs (third-party funded project)

Problem

Arc welding processes like gas metal arc welding (GMAW) and tungsten inert gas welding (TIG), in particular, are widely used in metal processing. The processes require noticeable innovations in order to remain competitive as a cost-effective joining technology considering new materials and increased requirements. At the same time, process safety and efficiency take precedence. Such innovations are only to be achieved on the basis of a detailed understanding of the mechanisms of action in the arc that previously did not exist sufficiently.

Problem-solving approach

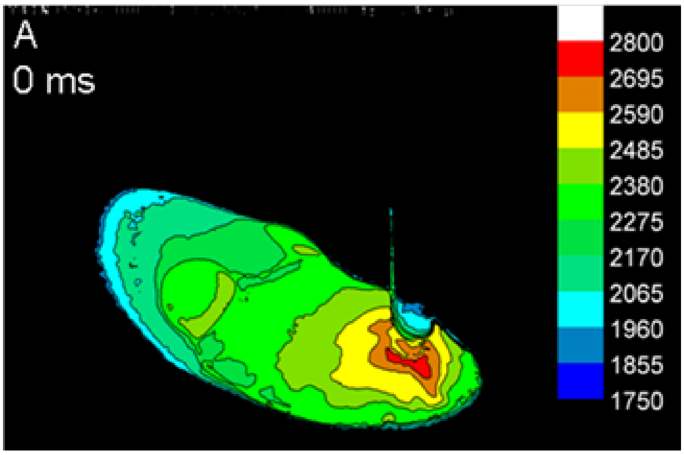
In the follow-up to a joint venture involving six German institutions for the study of GMA processes, it was possible to raise funds and start new projects related to fundamentals and applications with the partners TU Dresden, UniBw Munich, Laser Centre North (Hamburg) and the Laser Centre in Hanover. In the context of these projects, the INP uses methods of optical emission spectroscopy (OES) and high speed cinematography for the analysis of arc and material transition. In particular, there were studies of the fundamentals in TIG processes, including the effect of lower power laser radiation. In addition, practical GMA processes of steel under the influence of various shielding gases were analyzed. One of the main focuses was the development of magnetohydrodynamic simulations of the arc while avoiding the assumption of the local thermodynamic equilibrium and the adjustment to the description of the electrode fall regions in the case of arc welding with non-consumable electrodes.

Technological benefits

The results from the research on the fundamentals have been incorporated into the development of innovative process concepts such as laser-supported arc or plasma welding, as well as in the development of new control concepts. Both are primarily used to increase the stability and process reliability, as well as the efficiency of the welding process.

Results in 2012/13

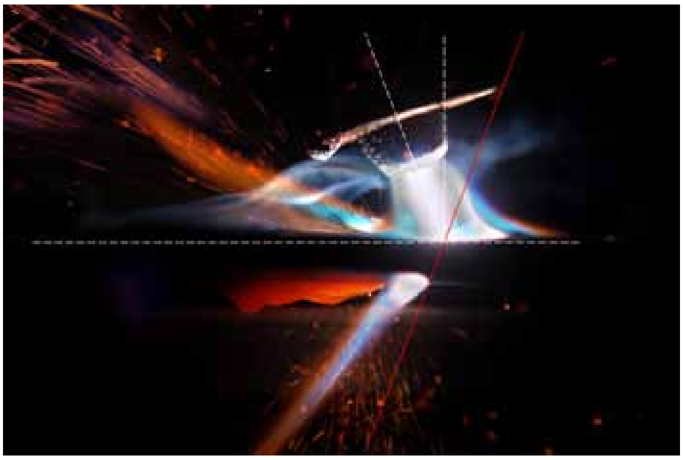
- Calculation of the cathode fall voltage and electrode temperature in the TIG process with the help of a non-equilibrium model for free-burning arcs
- Explanation of the positive effect of laser radiation on the molten bath behaviour and the seam quality in laser-assisted plasma welding
- Explanation of the arc attachment at the wire and the impact on the transfer of material for the DC-GMA welding under different shielding gases
- The model-related recording of the laser absorption in the arc for laser-assisted TIG welding



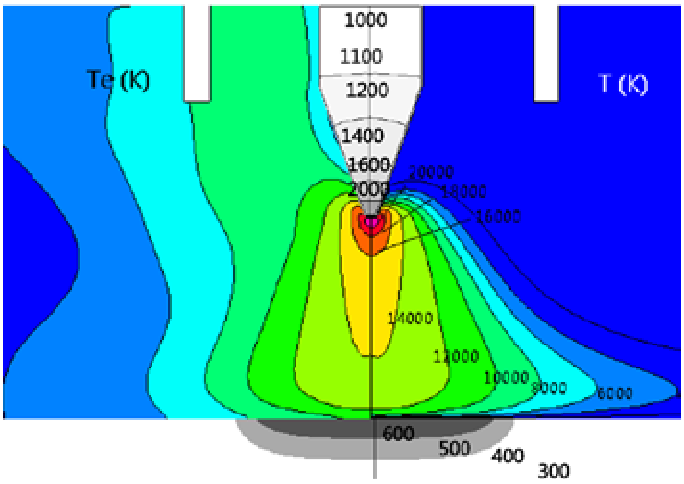
Surface temperature (in K) of the molten bath in a GMA process for steel with short circuits as determined from a high-speed recording

Plans for 2014

- Specification of non-equilibrium models on the simulation of GMA processes
- Study of the mechanisms of action and effectiveness for the use of complex shielding gas mixtures in the GMA process
- Experimental and theoretical analysis of the effect of laser radiation in laser-assisted TIG welding



Evidence of the formation of the needle hole effect for laser-assisted plasma welding with the aid of superimposed high-speed images



Calculated temperature distribution in the TIG arc (right: electron temperature, left: heavy particle temperature), as well as in the electrode and the work piece

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German Research Foundation - Alliance for Industrial Research (DFG-AIF)

Project partners:
TU Dresden,
UniBw Munich,
Laser Centre North (Hamburg),
Laser Centre Hanover

Switching arcs (core-funded project)

Problem

In a number of applications involving the supply of energy, thermal plasmas represent the essential functional components. Research into the relevant plasma processes is the basis for a significant further development. The mastery of switching operations with higher electrical currents at all voltage levels (low, medium and high-voltage technology) requires the safe operation of equipment and systems. The development of switching devices at today's technical level, and increasingly in light of environmental aspects, is no longer conceivable without physics-based simulations of the functional component plasma and accompanying experimental studies.

Problem-solving approach

The often sophisticated 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 consumption was observed in the switchgears under realistic working conditions. For the example of a gas switch according to the self-blast principle, the emission spectrum of the plasma is determined by radiation of the eroding nozzle material and often also the eroded electrode material. Established OES evaluation methods are specialized either on optically thin plasmas (negligible absorption of the radiation) or for special cases on self-reversed line profiles. For the determination of plasma parameters in plasmas of high optical depth, combinations of spectrum simulation and analysis have been developed as a general solution approach, allowing for the study of not yet recordable parameter ranges.

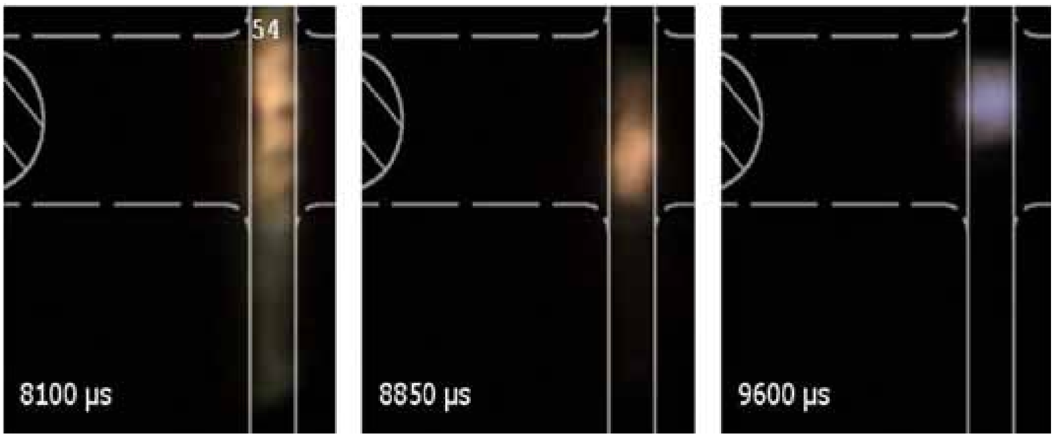
Technological benefits

The novel diagnostic methods of arc plasma lead to a deeper understanding of the physical processes as a prerequisite for new ideas and concepts for improved procedures. The use of such methods for parameter and design optimization will save significant time and costs in the development of switchgears.

Results in 2012/13

In joint research with RWTH Aachen, the temperature and pressure in a CO_2 model switchgear was determined for the first time with the aid of optical emission spectroscopy. The method was qualified in further studies for highly dynamic arc plasmas.

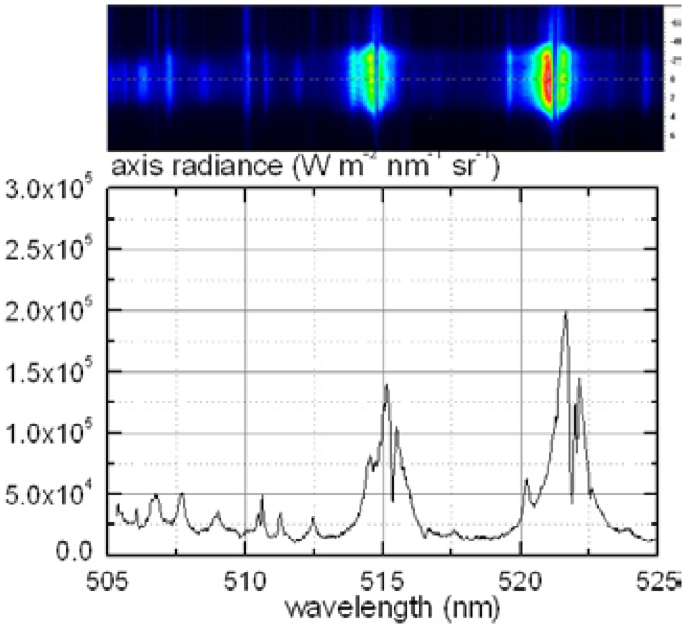
For the analysis of the radiation of arc plasmas with high optical depth, a simulation-based method has been developed. This method helped provide the first insights into temperature and pressure distribution in metal vapour-dominated arc plasmas.



High-speed imaging of an arc through the heat crack in a model switch at the final phase of a half-wave

Plans for 2014

- Transfer of existing optical diagnostic methods to vacuum arcs
- Characterization of metal vapour diffusion and the erosion behaviour in vacuum switches under variable conditions
- Development of non-equilibrium models for vacuum arcs
- Adaptation of absorption-spectroscopic diagnostic procedures to arc plasmas



Spectrum with strongly widened copper atomic lines close to the cathode of a metal-vapour-dominated arc at 1.5 kA.

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Sponsor:
Low-fundet projekt industry with support from

Project partners:
RWTH Aachen, ABB Switzerland

Loss of the night (third-party funded project)

Problem

Wide application of artificial lighting has a positive impact on security and prosperity and leads to an improvement in the quality of life. But these achievements are accompanied by significant adverse effects for the environment, nature and man. "Light pollution" is increasing, with largely unknown effects on humans and nature. Areas close to water are particularly affected. The transition zone of water - land is a unique area with a large number of endangered aquatic and terrestrial animal species (fish, birds, bats, insects, etc.). The ecological, chrono-biological, cultural and socio-economic causes and effects of increasing lighting at night in aquatic and adjacent terrestrial habitats should be setting priorities for the protection of man and nature, as well as developing the first lighting concepts, while taking into account social, energy, health and environmental concerns, with the long-term goal of defining scientifically based indicators and guidelines for sustainable lighting.

Problem-solving approach

A joint project by eight German institutions (AIP Potsdam, FU Berlin, UFZ Leipzig, IfADo Dortmund, INP Greifswald, IRS Erkner, IZW Berlin, TU Berlin) was funded by the German Federal Ministry of Education and Research (BMBF). In it, the extent and the causes of the loss of night were studied, and the ecological, health and social impact of light pollution on aquatic and adjacent terrestrial habitats (including their social construction) were analyzed. In laboratory and field trials, the impact of exterior lighting on ecosystems has been investigated. To achieve this, appropriate lighting systems had to be designed and characterized first.

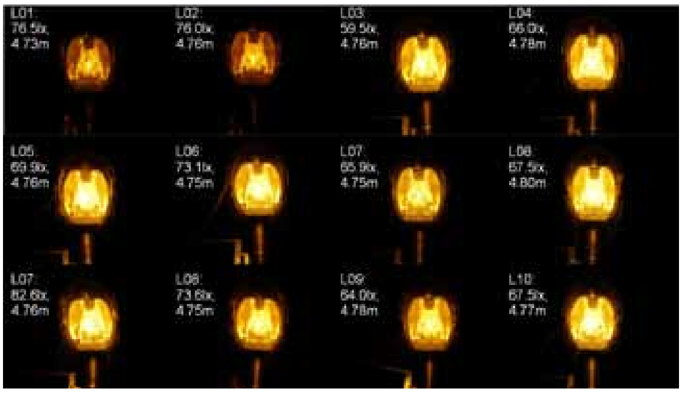
Technological benefits

The interdisciplinary scientific discussion on the importance of the night and its loss makes it possible to limit the negative ecological, physiological, health or socio-economic impacts, and also develop sustainable lighting concepts for future limited nocturnal landscapes for the benefit of the environment, nature and man.

Results in 2012/13

Within the framework of the joint project, biological investigations were accompanied by lighting technology. In Westhavelland, an outdoor experiment was set up. One field was lit with sodium vapour lamps; another field remained dark. In cooperation with the Lighting Technology Department at Berlin Technical University, the illuminated field was characterized in terms of lighting technology and the various permanently installed sensors for radiation measurement were evaluated.

The photos of the lamps shown below were taken after one year of operation. The strength of the illumination below the lights was determined at ground level. An area between four lights was measured according to the standards for the characterization of street lighting. The results were compared with simulations of the lighting. They allow for an extrapolation of the illumination levels even for positions that were not explicitly measured.



An experimental lighting of aquariums was set up and measured at the Leibnitz Institute of Freshwater Ecology and Inland Fisheries in Berlin (IGB Berlin). The secretion of melatonin by the fish into the aquarium water was mathematically modelled.

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Sponsor:
German Federal Ministry of Education and Research (BMBF)

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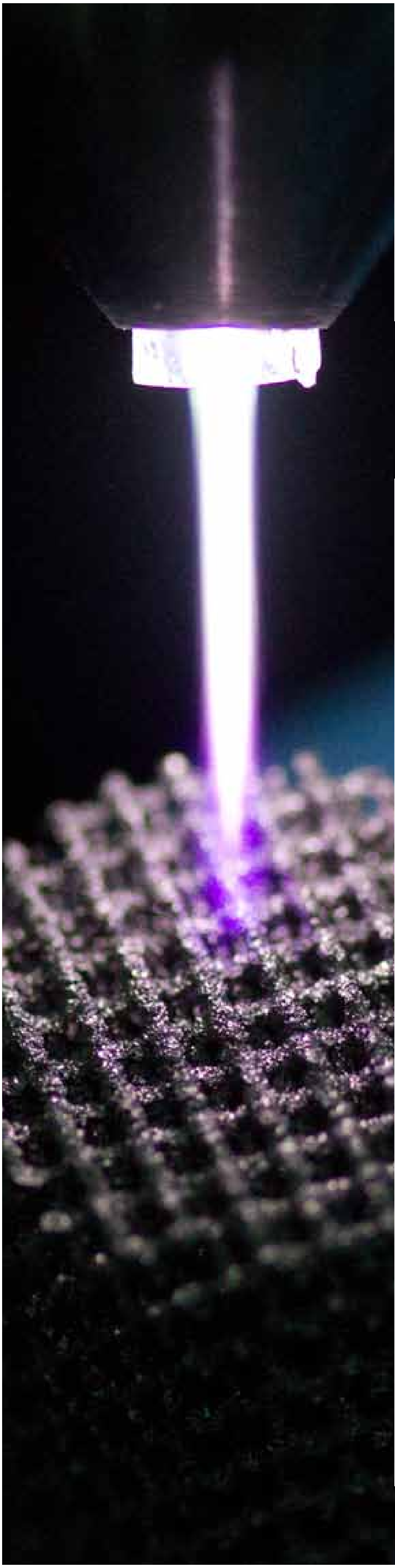
UFZ Leipzig,
IfADo Dortmund,
INP Greifswald,
IRS Erkner,
IZW Berlin,
TU Berlin



RESEARCH DIVISION

ENVIRONMENT & HEALTH

Overview

This Research Division pursues interdisciplinary research at the interface of plasma research and life sciences. It has been demonstrated that plasma technology in collaboration and exchange with other sciences (medicine, microbiology, molecular biology, chemistry, environmental sciences, etc.) has considerable potential to provide solutions for major societal challenges. The central and overarching competencies in INP's research programmes of plasma sources and plasma diagnostics are combined with research area-specific competencies for the study of biological plasma effects as well as investigations in the field of liquid analytics. In this way, research results are obtained on topics that are highly relevant for the development of health care solutions and environmental technologies. Accordingly, these topics constitute the research priorities of the Research Programmemes (RP) on Plasma Medicine/Decontamination, Bioactive Surfaces, Pollutant Degradation and Bioelectrics. Findings and results in these areas are expected to be transferred to practice-relevant applications in the future..

Research Programme Bioactive Surfaces

- Fundamentals of the production of cell-adhesive surfaces through deposition with atmospheric pressure plasmas
- Infusion systems with microbicidal surface properties (Centrifluidic Technologies)
- Anti-adhesive, plasma-chemical preparation of surfaces of temporary implants (Campus PlasmaMed)

Research Programme Plasma Medicine/ Decontamination

- Plasma sources for biomedical research
- Plasma-liquid interactions
- Plasma and food
- ZIK plasmatis (cellular effects and extracellular effects of plasma exposures)

Research Programme Pollutant Degradation

- Fundamentals of filamented plasmas
- Treatment of diesel exhaust
- PlasTEP

Research Programme Bioelectrics

- Fundamentals regarding the effects of pulsed electric fields on cells and tissues
- Degradation of pharmaceutical residues in water

Introduction

Physical plasma processes are preferred for systematic control of the interface properties of different sized, complex components and materials by functionalization through the gas phase and also by the deposition of functional films. Respective processes are carried out under both low pressure and atmospheric pressure conditions. The areas of application vary widely and depend on the substrate properties and the necessary handling. In terms of process technology, plasma processes offer many advantages such as low thermal stress and as a consequence a negligible effect on the properties of the base material, very good gap penetration, environmental benefits, a very low cost factor and easy handling and integration into existing production chains and processes, in particular for plasmas at atmospheric pressure. Nevertheless, the demands on such plasma processes are increasing, above all with respect to the development of new applications for outstanding quality surface functionalization.

The Research Programmeme Bioactive Surfaces is concerned with the development of plasma-based processes for the treatment of material surfaces (polymers, metals, ceramics, and glasses) that are used in the biomedical field. Subject areas such as the equipping of surfaces with cell-adhesive or even anti-adhesive, as well as antimicrobial properties, and their combination by means of special mask processes, are the focus of the investigations. Other fields of research deal with protein-adherent and photocatalytic surfaces.

Besides fulfilling high scientific expectations, the increasingly application-oriented Research Programmeme is consistently striving for the transfer of results to industrial applications. For this reason, a variety of industry-related facilities and laboratories were set up during the reporting period. High purity and defined applications in low pressure were developed through a novel system for the combination of the film deposition in the HiPIMS mode with the enrichment of the substrate material by plasma immersion ion implantation, designed specifically for the homogeneous processing of complex-shaped 3D substrates. In order to meet the industrial expectation of an in-line process under atmospheric pressure, various systems and procedures for surface finishing with jet plasmas and with dielectric barrier discharges were developed. In addition, the spectrum was expanded by adding a plasma spraying system and a system for the plasma-polishing of surfaces.

Homogeneous surface finishing of a hip joint.

Application potential

Controlled surface finishing by plasma-chemical processes for

- different materials, especially heat-sensitive materials (polymers, metals, ceramics, glass);
- adjustment of hydrophilic/ hydrophobic surface properties;
- 3D mouldings with complex structures.

Application of atmospheric pressure plasmas (spot type and two-dimensional) for the processing of complex 3D moulds for

- cell-adhesive surfaces; anti-adhesive surfaces;
- fine polishing of surfaces

Application of low pressure plasmas (spot type and two-dimensional) for the processing of complex 3D moulds for

- equipping of implant surfaces with antimicrobial properties;
- oxidation, nitridation and hardening of surfaces;
- cell-adhesive surfaces;
- anti-adhesive surfaces;
- structure-guided cell growth;
- systematic control of corrosion;
- protein-adherent surfaces;
- photocatalytic surfaces.

Examples for applications:

Disposables

- cell culture chips
- DNA chips
- biosensors
- high throughput screening systems

Therapeutic devices

- catheters
- dialyzers
- pacemakers

Implants

- prostheses
- tendons and ligaments
- vascular grafts
- stents
- heart valves

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Fundamentals in the production of cell-adhesive surfaces by means of depositing atmospheric pressure plasmas (core-funded project)

Problem

Biomaterials present in part chemically inert surfaces and thus often do not meet desired requirements for the growth of living cells. Plasma-assisted processes for surface modification allow producing bioactive surfaces for medical technologies such as implants, medical devices and consumables for biomedical diagnostics. Plasma-induced processes with process temperatures of less than 40°C are particularly suited for the modification of polymers and other heat-sensitive materials. Especially plasma-polymerized functional films are predestined to prepare materials with long-lasting desired properties. A considerable share of plasma processes that are used to this end are operated at low pressure. However, processes at atmospheric pressure promise a more straightforward implementation in existing in-line processes as well as easier handling. Moreover, surfaces can be modified selectively by using locally-acting plasmas such as jet plasmas.

Problem-solving approach

The use of atmospheric pressure jet plasmas for film deposition is being studied for the fabrication of cell-adhesive films. Using nitrogen precursors, the influence of different process parameters, such as the gas flow of carrier and precursor gas, is examined with respect to film deposition and composition.

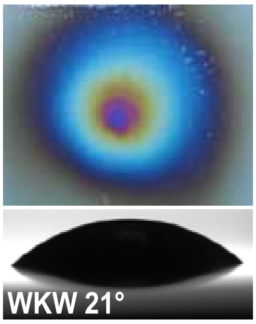
Technological benefits

The plasma-modified surfaces can be used to optimize implants or cell culture systems. The application for surface modification is not limited to flat substrates. For example, substrates with complex geometry as well as porous or otherwise structured materials can be treated by plasma jets with very good depth penetration. The absence of vacuum technology makes the atmospheric pressure plasma technology particularly interesting and advantageous.

Results in 2012/13

Using a nitrogenous raw material made it possible to deposit a chemically homogeneous and locally limited film (PPC-N) by a plasma-assisted process. Mass deposition rates of 0.1 - 0.6 µg/s and film growth rates of 0.3 - 3 nm/s were achieved. By varying the process parameters, both the thickness of the film as well as the lateral expansion of the growing film can be controlled.

Derivatization techniques allowed for the verification of a high amino group density $[NH_2]/[C]$ of 6%, which can be crucial for the adhesion and proliferation of human cells.



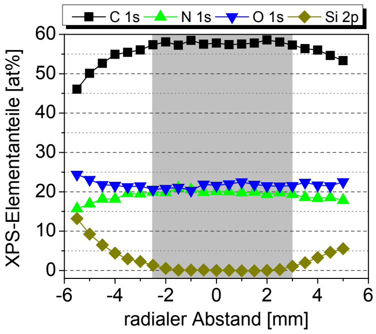
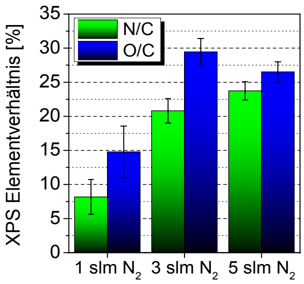
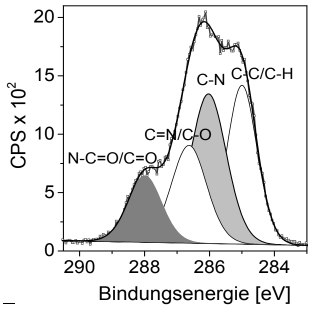


Image of a PPC-N film deposited on a silicon wafer and the resulting water contact angle of 21° (left). XPS line scan of the film for the tracking of the quantitative composition as a function of position (right). The graph shows a homogenous coating over a range of approximately 6 mm.





Influence of process parameters on the chemical composition of the PPC-N film (left). The corresponding gas flow allows control of the O/C and N/C ratios for the film. The C 1s signal shows four different bonding states that can be assigned to oxygen- containing and nitrogen-containing functional groups (right).

Plans for 2014

- Increase of the number of available atmospheric pressure plasma sources for the generation of bioactive surfaces, in particular dielectric barrier discharges.
- Improvement of the film stability on different materials through conditioning of the plasma processes.
- Use plasma-diagnostic methods for the basic understanding of the deposition mechanisms.
- Cell-biological studies in order to test the biocompatibility of surfaces as well as the adhesion and cell proliferation of human cells.

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Intravenous drip systems with microbicide surface properties (Centrifluidic Technologies // third-party funded project)

Problem

Intravenous drip systems are indispensable in modern hospitals. They are used for the administration of drugs, for the transfer of nutrients into the blood stream, but also for the taking of blood samples. Intravenous drip systems consist of a variety of different components such as valves, lines, filters, connectors for the drip or the syringe needle, all the way to venous catheters, which produces a direct connection to the blood stream. These components are single-use systems and are completely exchanged every 24 hours to prevent infections from bacteria, viruses or fungi.

The objectives of the "Centifluidic Technologies" growth centre are, on one hand, to reduce the risk of infections and, on the other hand, to extend the use of the infusion systems significantly. In this way it would even be possible to accomplish safe usage in outpatient settings and in the home care sector. This means not only drastic potential savings for the health care system, but foremost also an improvement in the patients' quality of life.

Problem-solving approach

Luer-Lock connections and valves are at potential risk since there is a discontinuity in the sterile system in combination with contact to the clinical staff. In order to make these sites safer, they are prepared with antimicrobial surfaces. Therefore, especially antimicrobial metals such as copper and silver can be used. With the help of plasma technology, the substrate material is either coated with these metals or the metals are introduced into the material. Even a combination of the two processes is possible.

Technological benefits

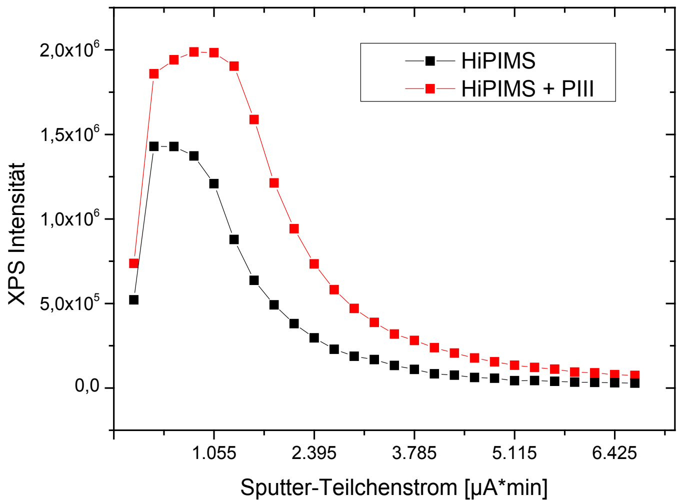
Using the plasma-based procedure for the coating and enrichment of the substrate material, and in particular the combination of both methods, a wide variety of unique surface properties can be adjusted. This applies not only to the precise control of the initial release of the antimicrobial metals, but also to the antimicrobial long-term impact that can be predefined. The understanding of the physico-chemical processes in the plasma and at the interface with the substrate also allows for a large number of new applications both in the biomedical area as well as in other high-tech areas.

Results in 2012/13

It has been shown that in particular the combination of processes for surface coating and enrichment has great application potential. Coatings are applied with 2 magnetron sputter sources under high power pulse operation (HiPIMS) – the plasma immersion ion implantation (PIII) has been carried out in parallel with a pulse voltage of up to -15kV.

Both methods complement each other perfectly, because in the HiPIMS method a very high ionisation rate of up to 80% can be achieved and simultaneously the production of in part up to 4-fold charged ions is possible.

The results of these studies have shown that the combination of the two procedures can considerably improve the film properties. The HiPIMS method allows producing very smooth surfaces. The combination of the procedures reduces the roughness by another factor of 3. HiPIMS allows for the production of crystallites in the film. The combination process increases not only the proportion of crystallites, but also their size by up to 50% for the same processing time. Even though the deposition rate in the HiPIMS mode alone is low when compared to other sputtering methods, this can be improved by the combination process.



Comparison of the depth profiles of copper deposited on acrylonitrile-butadiene-styrene (ABS), by either HiPIMS method alone or by combination of HiPIMS and PIII methods.

Due to the high deposition rate in the combination process, a sufficiently thick film can be deposited on surfaces within less than 1 minute with respect to the inactivation of the bacterium S. aureus by more than 6-log steps. The unique design of the plasma system developed at the INP Greifswald also allows for the homogeneous processing of complex 3D components up to a size of 20cm x 15cm.

Plans for 2014/2015

In future work, a basic understanding of the combination process and also the application possibilities in the area of high performance films will be developed.

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University of Rostock,
RoweMed AG,
Litronic GmbH,
DST Diagnostische Systeme & Technologien GmbH,
Cytocentrics Bioscience GmbH,
Beckmann Institut für Technologieentwicklung e.V.,
University of Greifswald,
Albutec GmbH,
Plasotec GmbH and HNP
Mikrosysteme GmbH

Anti-adhesive, plasma-chemical equipping of surfaces of temporary implants (Campus PlasmaMed // third-party funded project)

Problem

The use of metallic implants made from titanium and titanium alloys in orthopaedic and trauma surgery are state-of-the-art. Implant surfaces should ideally be designed to support subsequent clinical therapies. Temporary implants such as intra-medullary nails, screws or external fixators have to provide mechanical stabilization for bones. Furthermore, they should grow into the bone as little as possible so that they can be removed without any difficulty after the healing of a fracture. Cells or tissues should therefore adhere as little as possible to the interface. An anti-adhesive coating would be particularly advantageous for temporary implants in order to avoid biofilm formation and a build-up of cells.

Problem-solving approach

In the joint project Campus PlasmaMed, low temperature plasma processes were used for the modification of titanium surfaces. A plasma fluorocarbon polymer (PFP) was deposited by means of a microwave plasma and using a mixture of fluorinated hydrocarbon and hydrogen as precursor. Ideal anti-adhesive conditions that inhibit the growth of osteoblasts (bone cells) were achieved by creating a defined chemistry and specific functional groups on the surface. Close cooperation with the Department for Cell Culture at the Rostock University Medical Center, a project partner in Campus PlasmaMed, was indispensable for the optimization of the surface properties of metallic implants coated with PFP.

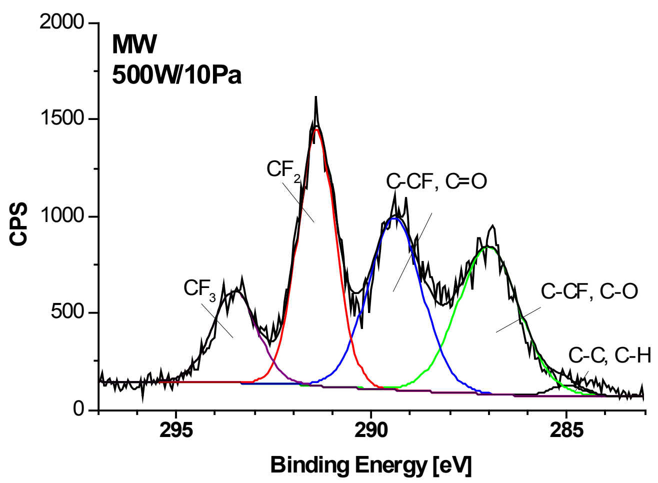
Technological benefits

The INP developed plasma-assisted processes within the framework of this project in order to modify metal surfaces in a cell-repellent way. Patients could directly benefit from the technology since complications during the healing process after the removal of temporary implants could be prevented.

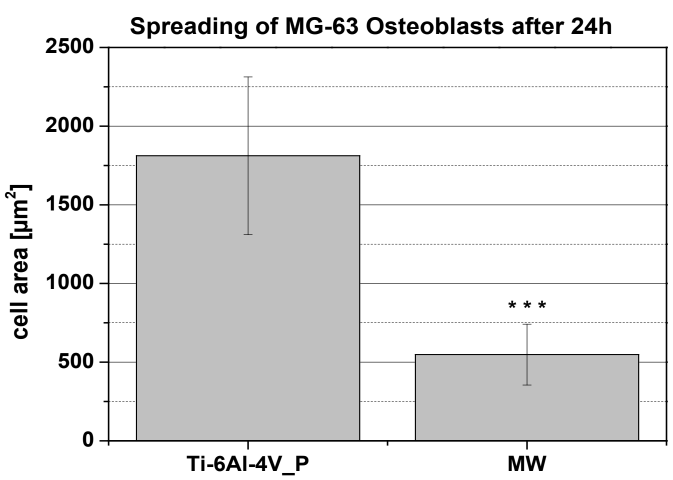
Results in 2012/13

A CW (continuous wave) microwave low pressure discharge allowed for the deposition of the desired anti-adhesive films, consisting of PFP on a titanium alloy. The hydrophobic films are still stable after 10 minutes of treatment in an ultrasonic bath. The water contact angle is 110o and the F/C ratio is 1.5. The XPS-spectrum confirms a well cross-linked PFP-film.

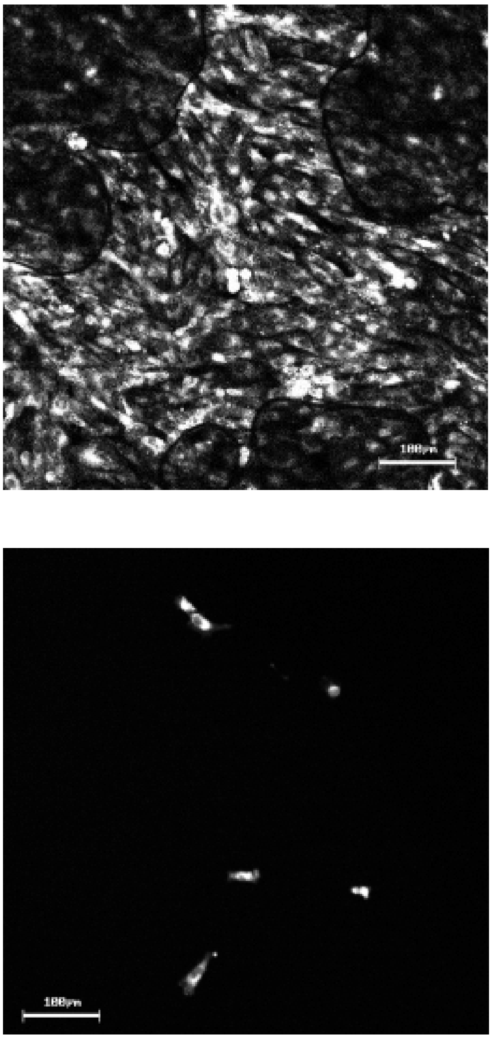
In vitro experiments have shown that it is possible to use PFP to drastically reduce the cell count and size of MG-63 cells.



High resolution XPS-C 1s spectrum of a well cross-linked PFP-film



Area covered with MG-63 osteoblasts on PFP after 24h



MG-63 osteoblasts on polished Ti-6Al-4V (top), and on PFP (bottom);
Dimension of bar=100µm

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Sponsor:
German Federal Ministry of Education and Research (BMBF)

Project partners:
Campus PlasmaMed,
esp. Universitätsmedizin Rostock

Introduction

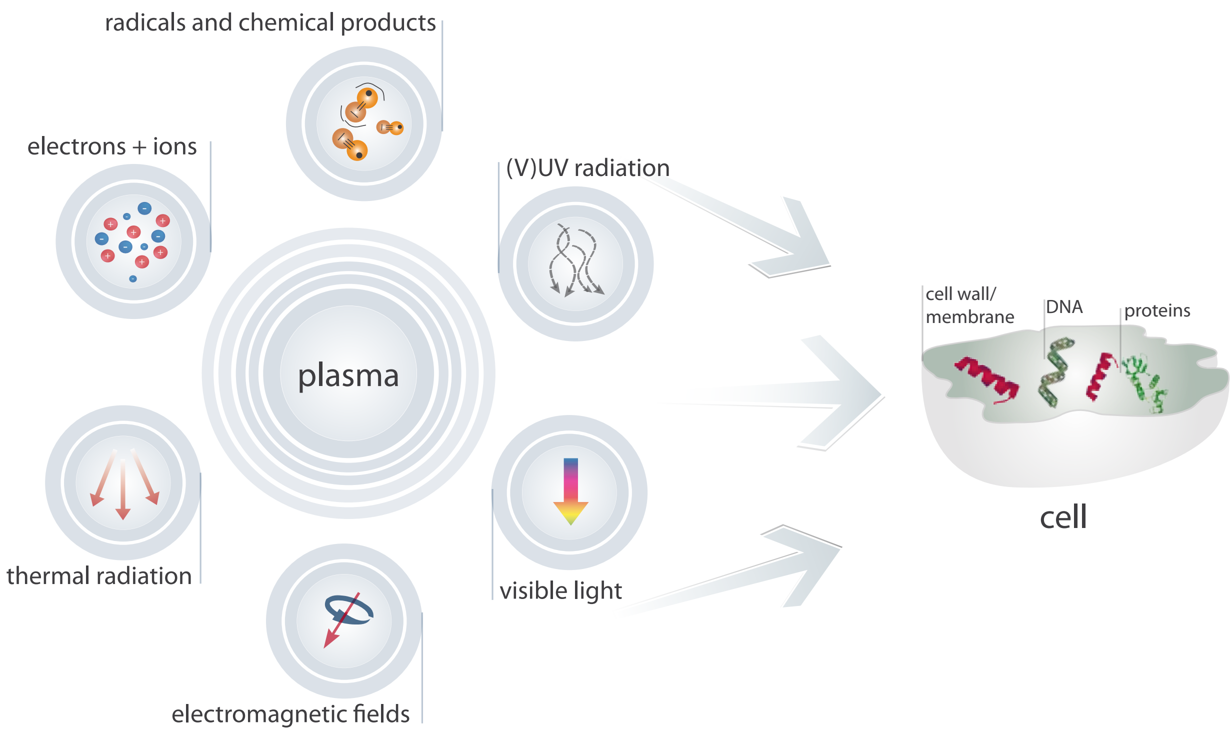
The research of the influence of physical plasmas on cells and tissues with the aim of medical use is an innovative field of research, which has experienced significant growth for several years and is described now under the name of plasma medicine. Closely related to the interest in medical applications is the use of plasma for the inactivation of micro-organisms with the aim of decontaminating materials, surfaces and products. A prerequisite for a successful practical implementation of both fields of research is the fundamental understanding of biological mechanisms that are induced by physical plasma. The Research Programmeme of "Plasma Medicine / Decontamination" will work in close cooperation with the INP-adjunct Plasmatis Centre for Innovation Competence (ZIK "plasmatis - Plasma plus cell") to conduct and coordinate research on the biological effects of atmospheric pressure plasmas and their possible applications.

The following research is at the centre interest:

- Design, development, characterisation and application of atmospheric plasma sources for biomedical studies, clinical tests and therapies
- Basic research on plasma-liquid interaction
- Basic research on the effect of atmospheric pressure plasmas on microorganisms and cell cultures
- Basic and application-oriented research with respect to the antimicrobial efficacy of atmospheric pressures plasma processes with the goal of using them for decontamination/sterilization/antiseptics

Projects 2012/2013

- Project Plasma & Cell on the fundamental interaction mechanisms
- Research network Campus PlasmaMed, managing the activities with respect to of plasma sources and the sub-project PlasmaVitro
- NormPlas - standardization of plasma sources for biomedical applications
- FriPlas - Application of plasma processes for gentle ¬preservation of produce, using for example post-harvest perishable food products
- Nanogiene - Renewable, hygienically effective nano-coatings on complex medical devices
- SafeFresh – Innovative monitoring and disinfection procedures to ensure microbiological safety in the production chain of fresh foods derived from crops
- LeguAN – Innovative and holistic, value-added concepts for functional food and feed from the local grain legumes
- EiPlas – Shell germ reduction for hatching and table eggs by means of atmospheric pressure plasma
- 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 on the inactivation of microorganisms by plasma processes is also becoming increasingly important for the treatment of foodstuffs and fresh produce. Here, the improvement of the durability and consumer protection is at the centre of interest.

Application potential

Plasma sources for biomedical applications:
- Providing sources for biomedical experiments and clinical tests
- Preparation of licenses and certifications for the approval as medical devices
- Standardization

Plasma-liquid interactions
- Production, optimization and/or stabilization of active substance liquids (plasma pharmacy)

Plasma cell interactions
- Characterization of biological effects of different plasma sources to provide a scientific basis for biomedical applications and to minimize risks

Antimicrobial plasma effects
- Decontamination/sterilization of packaging (food, pharmaceuticals), medical devices (endoscopes), implants, as well as foodstuffs and fresh produce

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Sponsor:
German Federal Ministry of Education and Research (BMBF)

Project partners:
See CampusPlasma Med

Plasma sources for biomedical research (Campus PlasmaMed // third-party funded project)

Problem

The funding agency of the research network "Campus PlasmaMed" stipulated the development of plasma sources that meet the requirements for licensing as a medical device. The requirement profiles for atmospheric pressure plasma sources for biomedical applications are very much dependent on the specific application. In the development of sources, it is necessary to consider physical performance parameters, the biological efficacy and also scalability. In addition regulatory constraints play a major role, such as for example specified by the Medical Devices Act. The necessary qualifying examinations for plasma sources take place during product development in an iterative way and are therefore very time-consuming.

Problem-solving approach

The development of plasma sources for biomedical applications is based on different principles for the generation of plasma (DBD, Corona, Jet, etc.). Accordingly laboratory prototypes were built at INP. The characterisation of the most important physical characteristics (temperature, electrical properties, and radiation) allows an evaluation of the general suitability of a specific configuration for intended use and purpose. In order to treat larger surface areas, the jet principle was expanded into a multi-channel arrangement (triple jet).

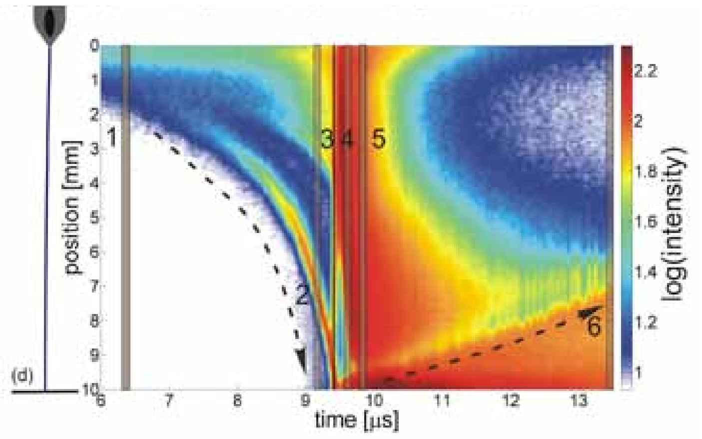
It is expected that results and experience gained during the process of the eventually successful licensing of kINPen MED as a medical device can in principle be drawn upon also for the licensing of the triple jet.

Technological benefits

Plasma medicine offers new approaches to treat a wide variety of diseases, in particular in the field of dermatology and dentistry. While scientific studies on the plasma-induced effects took precedence in the past, several manufacturers have now achieved the licensing of their devices as a medical device. This opens up a new market for medical devices. Based on the experience gained from the projects Campus PlasmaMed and ZIK plasmatis, INP now has the opportunity to design new sources in accordance with specific requirements and to explore their use in collaborations.

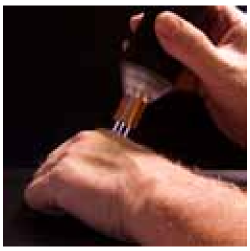
Results in 2012/13

- Electrical and optical characterization of the dynamics of a transient spark discharge by means of time-resolved and spatially-resolved diagnostics;
- Successful completion of the conformity assessment procedure for the plasma source kINPen MED, and successful licensing as a medical device;
- Transfer of the plasma jet source principle to a multi-channel arrangement (triple jet) and basic characterization of the physical performance parameters as well as biological effects.



Six regimes are identified in the spatially-resolved and phase-resolved radiation emission of the discharge generated at atmospheric pressure in a tip-plate arrangement

kINPen MED



Triple-Jet

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Sponsor:
German Federal Ministry of Education and Research (BMBF) – Campus PlasmaMed

Project partners:
neoplas tools GmbH,
Cinogy GmbH

Plasma-liquid interactions (core-funded project)

Problem

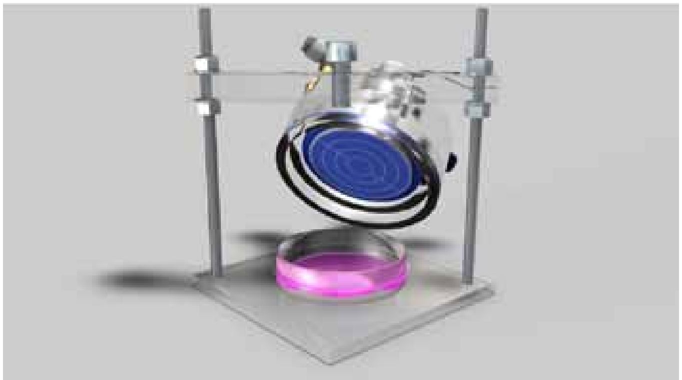
Plasma cell interactions are generally mediated by processes involving the aqueous environment. Highly reactive species are the final products of complex response chains of plasma-gas-liquid interactions. These species are difficult to detect and thus their identification is a chemical-analytical challenge.

Problem-solving approach

The research work on the explanation of the mechanisms of plasma-liquid interactions and their impact on biological systems was carried out with respect to two basic issues:

1. Identification of the reactive species responsible for biological plasma effects;
2. Options for the practical application of plasma-activated liquids.

The work was conducted in the framework of the fundamental project Plasma&Cell, and as part of the sub-project PlasmaVitro in Campus PlasmaMed. The surface dielectric barrier discharge (surface DBD) proved to be exceptionally suitable for the experimental investigations because pure plasma phase, gas phase and liquid phase with and without cells can be studied separately. The investigation of the plasma and gas phase was carried out by optical emission spectroscopy (OES) and by infrared spectroscopy (FTIR). Spectrophotometric procedures in combination with colour reactions as well as ion chromatography were used for liquid analytics. Vegetative microorganisms were used as model systems for assessment of biological plasma effects.



Surface DBD

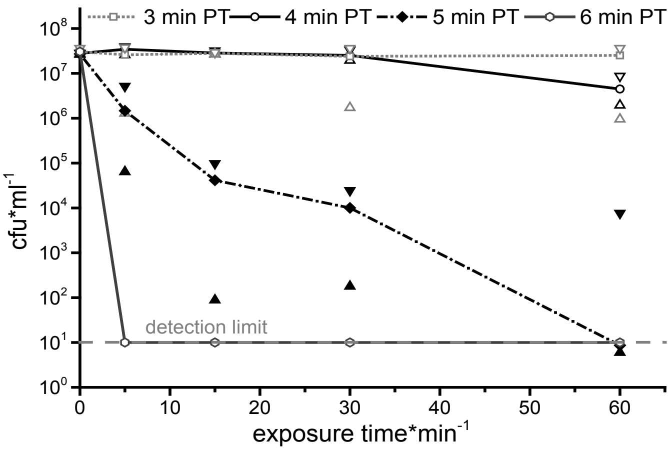
Results in 2012/13

A pivotal finding of the research work is the understanding that biological plasma effects are generally mediated through changes in the liquid environment cells. Primarily responsible are reactive oxygen and nitrogen species (ROS, RNS/RONS). This shows that the active parameters responsible for biological plasma effects are the same as those that can be found in normal metabolitic processes in living tissues. This makes the potential risks of medical plasma applications predictable and controllable, and also provides a solid scientific basis for plasma medical therapies (redox-based wound healing).

Furthermore, it was shown that plasma treatment of water makes it possible to produce a temporarily effective antimicrobial solution ("plasma-activated water"), the effectiveness of which is based on RONS together with an acidification of the liquid The strength and duration of action of such solutions can be varied within certain limits depending on the time of exposure to the plasma and the time of immersion of microorganisms.

Plans for 2014

- Explanation of antimicrobial mechanisms of plasma-treated water by transcriptome analysis,
- Identification of effective reactive species;
- Exploring practical fields of application for plasma-treated water.



Inactivation of E. coli by physiological saline solution that was treated with plasma for 3-6 min

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Plasma and food (third-party funded project)

Problem

Within the food production chain, there are often two core problems caused by microbiological contamination:

- Harvesting and storage losses
- Food safety

Producers and retailers of fresh produce have to pay more attention to food safety in order to reduce harvest and storage losses. This has been demonstrated dramatically by the problems with EHEC contaminations in 2011. The existing methods for the establishment of hygiene are not effective to the required degree, are not approved or do not represent the current state of the art. The inactivation of micro-organisms on vegetables and fruits while simultaneously retaining valuable ingredients in the plant matrix is a technological challenge that is still without solution.

Problem-solving approach

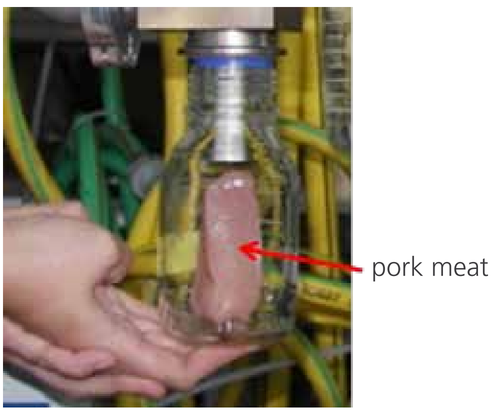
With the goal to keep expenditures for the process low, only relatively cost-effective methods are put to use. An upper limit in the method costs can be found in the high-pressure technology, as already seen for the industrial preparation of meat products. Vacuum processes with fresh produce are not possible due to the humidity. Therefore, methods on the basis of atmospheric pressure plasmas are very promising alternatives. The basic idea is the efficient generation of antimicrobial reactive species, in particular radicals and metastables, by means of plasma. These species remain microbiologically active only for typical processing times. Consequently, the potential impact on the product is minimised and a risk for the consumers can be excluded. Plasma generators in the frequency range from kHz to some GHz are used for the investigation.

Technological benefits

The successful development of new processes will lead to a more sustainable and more cost-effective agriculture. At the same time, consumer safety can be improved. Furthermore, it is expected that the developed decontamination processes can be used in other areas, such as packaging materials, transport containers, equipment parts and medical devices. Additionally, the results could have an impact on plasma chemistry.

Results in 2012/13

Cooperation with the German Research Foundation (DFG) Senate Commission for Food Safety (SKLM):
In cooperation with the Senate Commission for Food Safety, an opinion on the use of plasma processes for the treatment of food was prepared and published in Molecular Nutrition and Food Research.1)



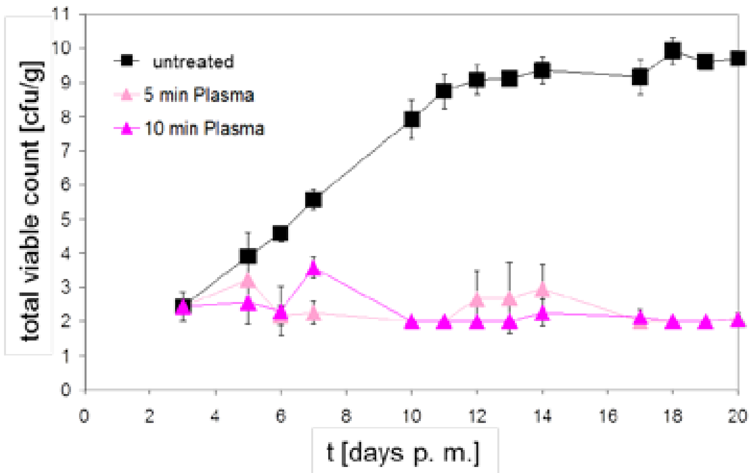


Figure 1a) Meat treatment using PPA; b) Change over time in the total bacterial count for PPA-treated and untreated samples

Meat treatment [2,3]

The microbiological safety of meat is of great importance for the meat industry. Meat is highly perishable and it reacts very sensitively to disinfection processes. The PPA processes (plasma processed air) based on the microwave-stimulated plasma source PLexc allowed an examination of the change in the ability to store fresh pork (see Fig. 1a). Samples were provided both untreated and PPA-treated for storage at 5°C. On defined days, the total bacteria loads were calculated as described in Fig.1b. The treatment for 2 x 2.5 min was sufficient to keep the total bacterial count for the entire storage period of 16 days at 5°C at 2 log colony-forming units per gram (CFU/g). Conversely, the total bacterial count of untreated meat samples rose to approximately 9.7 log CFU/g within the storage period.

[1] Oliver Schlüter, Jörg Ehlbeck, Christian Hertel, Michael Habermeyer, Angelika Roth,Karl-Heinz Engel, Thomas Holzhauser, Dietrich Knorr and Gerhard Eisenbrand: Opinion on the use of plasma processes for treatment of foods, Mol. Nutr. Food Res. 57 (2013) 920-927
[2] A. Fröhling, J. Durek, U. Schnabel, J. Ehlbeck, J. Bolling, O. Schlüter: Indirect plasma treatment of fresh pork: Decontamination efficiency and effects on quality attributes, Innovative Food Science & Emerging Technologies 16 (2012) 381-390
[3] Antje Fröhling, Kai Reineke, Jörg Ehlbeck, Oliver Schlüter: Potentielle Anwendungsmöglichkeiten von kaltem Plasma in der Fleischverarbeitung Rundschau für Fleischhygiene und Lebensmittelüberwachung 9 (2013) 327

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German Federal Ministry of Education and Research (BMBF)

Project partners:
ATB Leibniz Institute for Agricultural Engineering Potsdam-Bornim e.V. ,
Fraunhofer Institute for Process Engineering and Packaging (IVV),
company Löhrke GmbH
and IPAC-Labor GmbH

Plasmatis Centre for Innovation Competence (Cellular Effects and Extracellular Effects // third-party funded project)

Problem

Previous cell-biological experiments in plasma medicine were not only conducted with various plasma sources, but also with different cells (and tissues and/or organisms) and for very different conditions (partially not documented). This led to an almost unmanageable flood of data over the course of the years, but results are often not comparable between different studies. Thus, up to now, neither plasma sources nor effects on cells can be readily compared.

The Centre for Innovation Competence (ZIK) "plasmatis - Plasma plus cell" is aiming for a basic understanding of the interaction between physical plasma and cells regarding application in plasma medicine. The interaction of plasma with cells is essentially determined by the reactive components formed by the plasma.

Problem-solving approach

The route taken for the investigations is to take control of the physical parameters of the plasma in order to adjust the production of reactive components and the composition of the plasma and the treated cell culture media. This will allow for conclusions about the underlying processes.

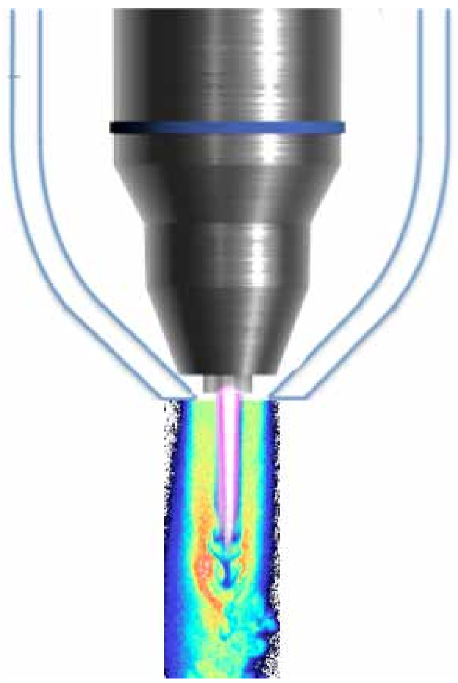

Figure 1: Plasma jet kINPen with the visualized gas flow of a developed shielding gas layer.

To this end, an appropriate integrated test system was set up, making it possible to compare various plasma sources, as well as different cells and tissues. An important step is the decoupling of the plasma jet from the environment (see Fig. 1).

Technological benefits

With a view to medium-term applicability of cold physical plasmas in the treatment of various diseases, the establishment of internationally agreed standards is indispensable. The creation of standardized treatment protocols is a necessary tool for the comparison of different plasma treatments/plasma sources – and is also an important step in the development of therapy-specific plasma applications. The availability of tailor-made plasma allows for a variety of applications and patient specific therapies.

Results in 2012/13

It was possible to establish a plasma-chemical, liquid and cellular test system for the plasma treatment of cells of various origins. The system is based on the Plasmatis Centre of Innovation Competence's fundamentally spatially-resolved and time-resolved plasma sources (kINPen09 and ceramic DBD). It is further including several molecular biological as well as physical diagnostics. Many parameters have been recorded and summarized for the specifications of a standardized plasma treatment. It was found that important boundary conditions such as distance, time, temperature, humidity, pH value, cell density, cell culture media for a comparable plasma treatment of a pre-determined specific cell line must be defined first in order to reasonably compare the treatment with different plasma sources. Similarly conditions must be determined to compare the effects on different cell types with a pre-determined plasma source. Notable is the interdisciplinary cooperation between the two ZIK-groups. Competencies of the physics-oriented junior scientist group "Extracellular Effects" (ECE) and the molecular-biological expertise of the junior scientist group "Cellular Effects" (PA) are effectively combined. This allowed for the discovery of the significance of the operating gas moisture with respect to reproducibility and stability of the cell biology experiments., It was further possible to discover individual biological reactions by controlling plasma parameter. These necessary boundary conditions are now considered in future experiments that are conducted by the two junior scientist groups, as well as the follow-up projects of Campus PlasmaMed.

Based on the developed standardized protocols, gene activation, protein changes and/or signal-forwarding that are observed for treatments with various cold plasmas are now examined. As a result, the first cellular signalling molecules that changed in their activity due to customized plasma treatments could already be addressed in detail. With this knowledge, it should be possible to describe different signalling cascades in order to control a systematic modulation of cellular activities, such as growth or secretion, by using cold physical plasmas.

Plans for 2014

- Analysis of the modulated gene activities, as well as the corresponding cellular proteins, with a focus on growth factors, enzymes and signalling molecules.
- Control of plasma generation and of plasma interactions with the environment, in order to systematically generate different active molecules.

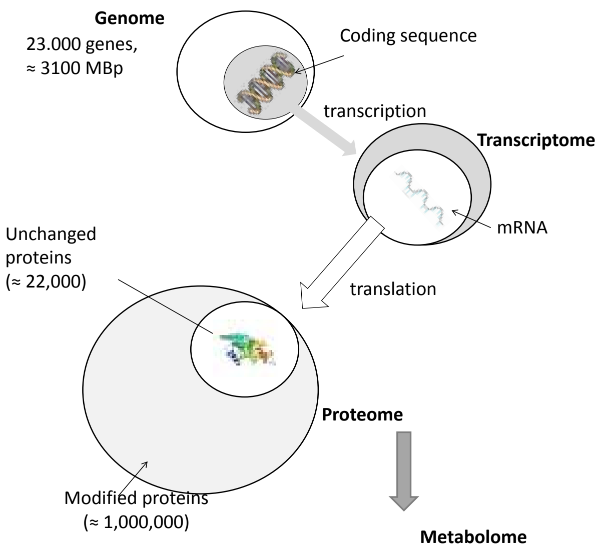

Figure 2: Workflow to find the plasma-based effects in human cells

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Sponsor:
German Federal Ministry of Education and Research (BMBF)

Introduction

Air pollution is an important societal issue, which is also reflected in increasingly strict statutory regulations for emissions in Germany (e.g. Technische Anleitung zur Reinhaltung der Luft (TA Luft). Despite enormous progress in air pollution control, there are still a number of air pollutants with concentration that are too high.

Plasmas show an effect on biological and chemical contaminations in gases, liquids and on surfaces, which offers potential solutions for environmental and health protection.

The special properties of plasmas in this context are:

- The reduction or transformation of harmful gases takes place without significant heating of the gas. Therefore the processes are intrinsically energy-efficient.
- Processes can be directly controlled by electrical operating parameters in a timely manner.
- It is possible to achieve effects on gas molecules and particles.

The work in this Research Programme includes a wide range of environmental and health-related tasks. Achievements and results can be summarized as follows:

- Development and characterization of new plasma sources for waste gas and exhaust air treatment, including analysis of and for the speciation;
- Observation of plasma-chemical processes for the decomposition of harmful species (nitrogen oxides, volatile organic compounds) and of synergies in combination with catalysts or adsorbers;
- Characterization of the effect of plasmas in application-relevant situations within feasibility studies as well as field tests and bench test trials;
- Diagnostics and simulation of filamented atmospheric pressure plasmas, in particular micro-discharges.

Regarding the last point, INP has a globally unique facilities and methods for the diagnostic of individual discharges.

Based on the findings on microdischarges, plasma sources and reactors are developed and investigated with respect to various tasks. Here, the combination with other methods (catalysis, adsorption, gas scrubbing) increasingly plays an important role.

Application potential

The potential application of non-thermal plasmas is, above all, the controlled degradation or conversion of noxious gases in contaminated gas streams, for example:

- Reduction of volatile organic compounds (VOCs) and other noxious gases and odours from manufacturing processes in combination with catalytic converters and/or adsorbers;
- Reduction of nitrogen oxides from combustion processes (diesel engines) in combination with catalytic converters;
- Reduction of noxious gas molecules and particulates in air-hygiene and ventilation/exhaust-air treatments.

Furthermore, discoveries in discharge physics can also make a contribution to the control and detection of partial discharges (microdischarges) at insulating barriers.

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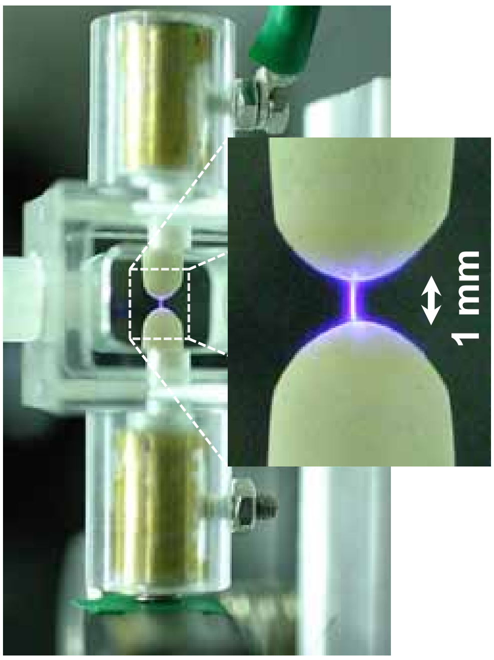
Fundamentals of filamentary plasmas (core-funded project)

Problem

The optimization of existing and/or the creation of new procedures for the degradation of pollutants require a comprehensive understanding of the relevant plasmas. This is a major challenge for plasma diagnostic methods and simulation efforts due to the filamentary nature of microdischarges. The analysis is further complicated by erratic, transient and generally short-lived characteristics. As a result, there is a lack of comprehensive knowledge in the field of molecular and reactive gas mixtures with respect to the discharge processes, their correlation with plasma-induced chemical reactions and the knowledge on resulting plasma parameters.

Problem-solving approach

The control of the plasma chemical processes determines their efficiency and selectivity. INP has been conducting precise and high-resolution studies for some years to describe the spatio-temporal discharge development. A better understanding of the discharge physics provides access to plasma parameters and offers suggestions for further optimisation of processes (reactor geometry, electrical operating parameters).



Test set-up for studying individual filaments

Experimental investigations are complemented by hydrodynamic modelling and kinetic analysis of the electron components. The focus of the research that is part of the Sonderforschungsbereich (Collaborative Research Centre) Transregio 24 "Fundamentals of Complex Plasma" in collaboration with the University of Greifswald and the University of Kiel. Fundamentals of the formation of barrier discharges (diffuse and filamented regimes) are examined. In addition to the study of the discharge physics, the role of surface discharges on the dielectric barriers is investigated.

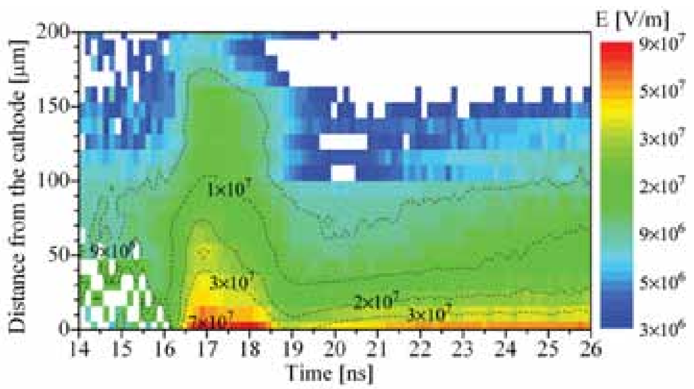
Technological benefits

- Optimization of existing plasma processes for pollutant degradation based on discharge physics;
- New approaches for the effect of operating parameters on the plasma-chemical conversion efficiency

Results in 2012/13

The work on electrical breakdown and the spatio-temporal behaviour of pulse-operated barrier discharges was continued. The effect of the pulse width on the discharge that was observed for a unipolar, asymmetric square-wave voltage could also be confirmed for bipolar square-wave voltages. The breakdown behaviour changes significantly for pulse widths that are on the order of the ion translation time (approximately 1 µs). They further affect initial breakdown phase ("Townsend Phase") of individual discharges.

Work on the diagnostic of DC-driven negative corona discharges was completed. For the first time, it was possible to detect the existence of a cathode-directed streamer during the development of Trichel pulses experimentally. These findings could contribute to a standardization of the theories on electrical breakdown in electron-negative gases. Furthermore, the reduced electric field strength was successfully determined based on a kinetic model and calibration.



Spatially and temporally resolved development of the electrical field strengths of Trichel pulses in air based on measurements using time-resolved individual photon counting

Plans for 2014

- Investigation and simulation of the spatial and temporal behaviour of discharges in reactive gas mixtures for a variation of gas temperature and gas composition;
- Investigation of the effect of polarity with respect to the dielectric barriers on microdischarge development;
- Experimental and theoretical analysis of the effect of edge steepness on discharge physics and plasma chemistry.

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Project partners:
University of Brno (Czech Republic),
University of Greifswald
and University of Pau (France)

Treatment of diesel exhaust (third-party funded project)

Problem

Nitrogen oxides are major contributors to eutrophication and acidification of the oceans and seas. For this reason, diesel emissions of nitrogen oxides will be strictly limited by future legislation. This can already been observed in a growing number of emission-controlled sea areas. Since internal engine technologies have reached their limits, exhaust gas after-treatment methods have moved into focus and are expected to solve the problem of nitrogen oxides in ships with diesel exhaust. Solutions should be available for the entire range of gross registered tonnage and all equipment units.

Problem-solving approach

One way of reducing nitrogen oxide emissions is the oxidation of nitrogen monoxide to nitrogen dioxide with a subsequent reduction to nitrogen and oxygen, by taking advantage of heterogeneous catalysis in both processes. Since oxidation catalysts at low temperatures are inactive, the oxidative effect of non-thermal plasmas in the form of AC-driven dielectric barrier atmospheric pressure discharges at low temperatures, complemented by suitable catalyst material, should be used. Another process optimization is achieved through the use of an additional oxidizing agent on a hydrocarbon basis. The efficiency and selectivity of this process are crucial for the application of such a system. For this reason, synthetic gas mixtures such as those emitted from marine diesel engines were treated in the laboratory in order to develop a complete filter system that was ultimately used in the bypass of a marine diesel engine.

Technological benefits

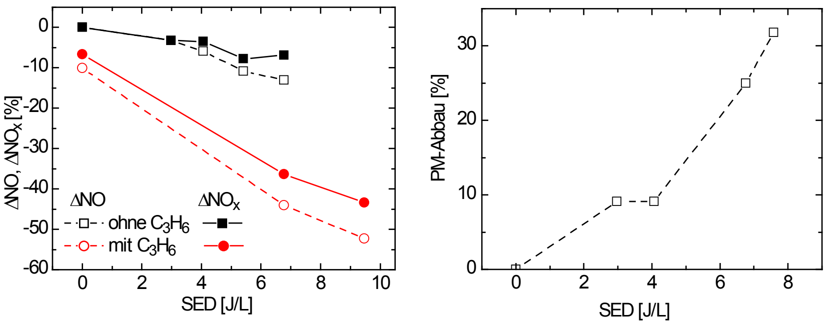
The technological benefit lies in the provision of filter technology for marine diesel engines which guarantees a significant reduction in emissions of nitrogen oxides in accordance with the future requirements for the protection of the environment and mankind. The solution should be cost-effective and save energy.

Results in 2012/13

A stack reactor that is based on a planar barrier discharge was used to examine the plasma effect in synthetic flue gas. Parameters and conditions that have been investigated were the energy dissipated into the plasma, the flue gas temperature and the effect of individual flue gas components. For the latter in particular propene as an additional oxidizing agent was added. The principle of the stack reactor was then scaled up for bench test trials at the project partner's site in Szczecin.

Stack reactor for test bench trials (left); installation of bypass in a marine diesel engine (right)

Previous laboratory results could be verified by the bench test. Oxidation of NO to NO2 with moderate energy input was demonstrated. The admixture of propane increases the efficiency of the oxidation significantly. In addition, a significant reduction of particulate pollutants (e.g. soot particles) was observed with for the plasma treatment.



NO oxidation and degradation of particles (PM particulate matter) in the test bench trials

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Sponsor:
German Federal Ministry of Economics and Technology (BMWi)

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Motoren- und Energietechnik GmbH (MET) Rostock,
Maritime University of Szczecin,
Chair of Technical Thermodynamics at the University of Rostock,
Leibniz Institute for Catalysis (LIKAT) at the University of Rostock.

PlasTEP (third-party funded project)

The control of environmental pollution is an international issue and thus also a strategic objective of the European Union. This is reflected in the increasing stringency of exhaust gas emission standards, especially in countries in the Baltic Sea area. The aim of the PlasTEP project: "Dissemination and fostering of plasma-based technological innovation for environment protection in the Baltic Sea region" is to explain the potential of plasma-assisted technologies for environmental protection to decision-makers in politics and industry. In addition the the obtained knowledge is promoted for the integration into the educational process of future generations. Another goal is to encourage investments in plasma-based environmental technologies. Accordingly PlasTEP is lobbying decision-makers by demonstrating: Plasma opens new doors Plasma technology is ground-breaking and there is a chance of more environmentally-friendly industrialization.

The PlasTEP project is conducted in the framework of the Baltic Sea Region Programme 2007 - 2013. This programme is part of the EU strategy for the Baltic Sea region and is co-financed by the European Union (European Regional Development Fund). 16 Partners from 8 countries are working together in this project.

Three thematic working groups were launched. Demonstration models and prototypes are expected to be developed that are then used for specific demonstrations. These are aimed at the degradation of nitrogen oxides, sulphur oxides and volatile organic compounds, as well as particulates from exhaust gases. Water purification using plasmas is also considered.

In addition to the research work, the sustainability of the plasma-based environmental protection technologies is discussed and their integration in education and training efforts. Accordingly, several workshops and three summer schools were set up.

Image of the mobile testing facility for field trials (right)

Results in 2012/13

A mobile plasma testing system was designed and built for field trial analytics for the detection of plasma-chemical effects was integrated together with the plasma technology. Field trials have been conducted at different sites in Poland, Estonia, Germany and Denmark. In some cases significant plasma effects were found. In addition to the field trials, innovative approaches have been tested such as a so-called case film reactor for plasma-assisted gas scrubbing that allows for the degradation of toluene and undecane from gas currents.

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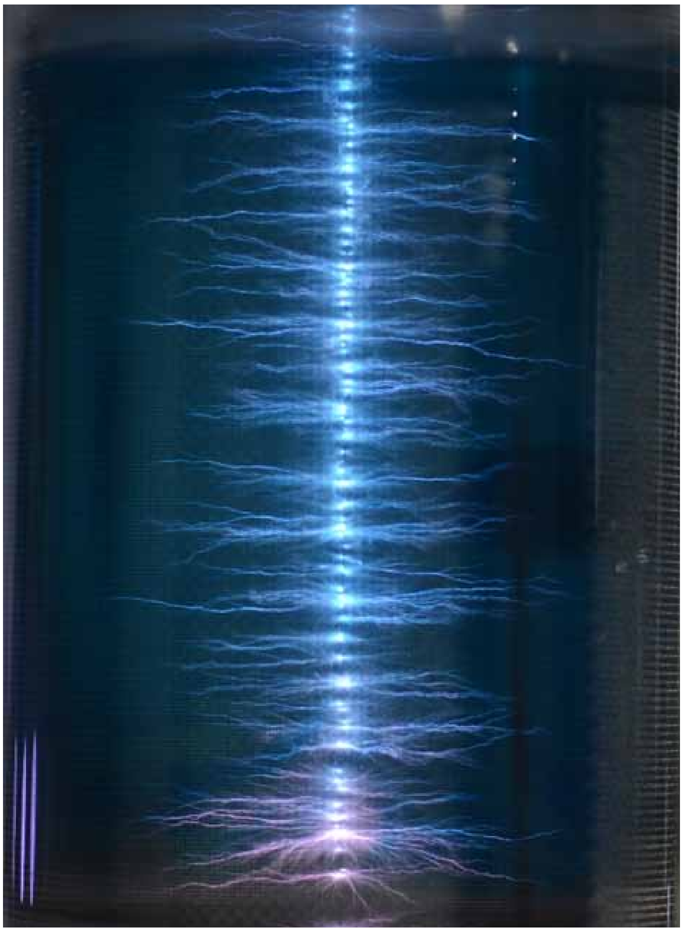
Sponsor:
Interreg IVb Baltic Sea Region (EU structure subsidy)

Project partners:
Technology Centre of Western Pomerania (TZV), VDI Mecklenburg Western Pomerania (VDI), Risø National Laboratory for Sustainable Energy, TU of Denmark (Risø), Uppsala University, The Ångström Laboratory (UUA), Lappeenranta University of Technology, ASTRal (LUT), Riga Technical University (RTU), Lithuanian Energy Institute (LEI), Kaunas University of Technology (KUT), Vilnius Gediminas Technical University (VGTU), Institute of Nuclear Chemistry and Technology (INCT), The Szewalski Institute of Fluid Flow Machinery (IMP), West Pomeranian University of Technology (SUT), University of Tartu (UT) and Association of Polish Electrical Engineers, Szczecin Branch (SEP)

Introduction

The Research Programme Bioelectrics investigates the manipulation of cells by electrical stimuli. Stimuli of interest are non-thermal plasmas, preferably generated at atmospheric pressure in air or water, and pulsed electric fields. Morphological and functional changes in cells, tissues and organs can be achieved, depending on the method and respective operating parameters. Plasmas are assumed to affect cells primarily by damaging cell membrane. Likewise, exposures to electrical pulses with long duration, i.e. on the order of microseconds or milliseconds, have been found n to temporarily or permanently permeabilize cell membranes – depending on the strength of the electric field. The reversible permeabilization can be used for drug delivery into cells or for the extraction of substances that are the produced by the cell. The irreversible permeabilization is an efficient method to kill germs. Conversely, strong, but short electric fields with durations of less than a microsecond can effectively penetrate into the cell and thereby instigate sustained changes to cell functions. Accordingly, organelles and even molecular structures can be affected.



Corona plasmas generated in water with the dye methylene blue added.

The Research Program Bioelectrics is also developing new procedures for the investigation of interactions between cells and matter that are exposed to short electrical fields and/or plasmas. As such, basic questions on the composition of cells and matter are explored. The Research Program took up its work in September 2011 and has been in development since then.

Application potential

- Biological decontamination and sterilization of organic tissues
- Drinking water and wastewater treatment
- Tumour therapy
- Modification of cells and tissues, i.e. acceleration of wound healing
- Understanding the discharge build-up in water
- Understanding the structure and cohesion of cell membranes
- Understanding the interaction of plasmas and electric fields with cells

Overview of technologies used and topics investigated in the Research Programme Bioelectrics with respect to different potential applications.

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Basic mechanisms regarding the effects of pulsed electric fields on cells and tissues (core-funded project)

Problem

Nanosecond pulsed electric fields (nsPEFs) can be used for the treatment of tumors. In animal studies it was shown that the treatment with nsPEFs can lead to complete regression of tumors (Fig 1). Experiments on single cells show that this is due to the induction of apoptosis. However, processes between cells in an alloplast or a tissue, i.e. cells interacting with each other, are not known.

Problem-solving approach

In order to understand the interaction of nsPEFs with tissue, the effects on cell monolayers are examined. The cells in a monolayer are directly connected with each other and can, equivalent to cells organized in tissues, communicate with each other via cell-cell connections (gap junctions).

Technological benefits

An understanding of the interaction of nsPEFs with tissue will help to develop more effective tumour treatments and assess possible side effects.

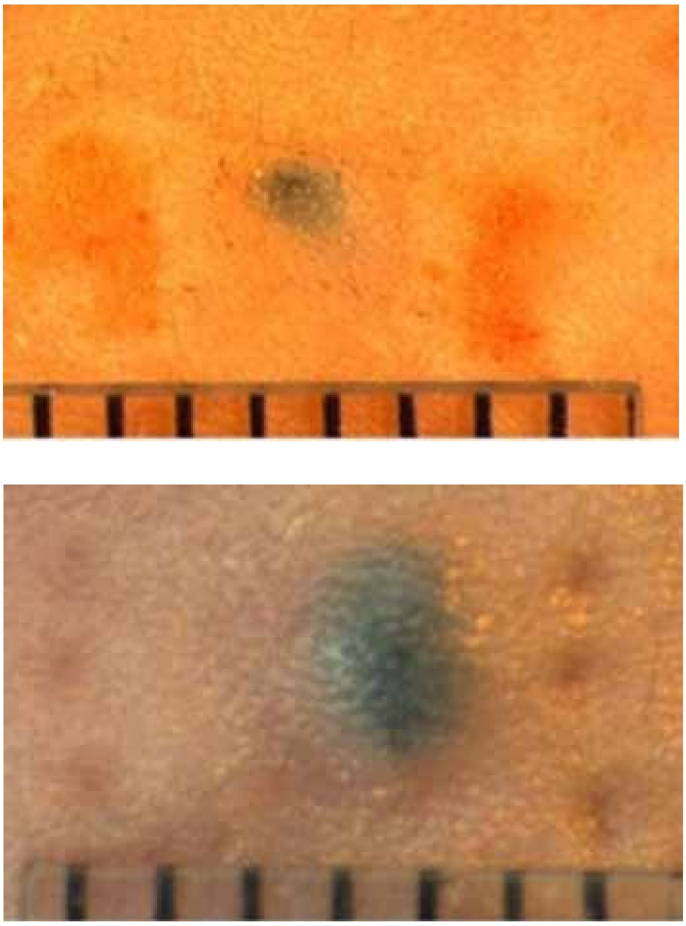

Figure 1: Melanoma in a mouse immediately after (top) and two days after the first treatment (bottom) with nanosecond pulsed electric fields (2 treatments, 100 pulse, 300 ns, 10 kV). The tumour has almost completely regressed.

Results in 2012/13

Cell lines that communicate with each other in a monolayer via gap junctions were determined (HaCaT, WB F344). In addition, methods for the investigation of cell-cell communication were established, such as scrape loading dye transfer (SLDT) and microinjection. First results suggest that the communication between cells is affected by the application of nsPEFs (Figure 2).

Plans for 2014

- Further studies on the changes in cell-cell communication
- Measurement of membrane potential changes
- Comparison of the biomechanical properties of cells in a monolayer using AFM measurements before and after the application of nsPEFs

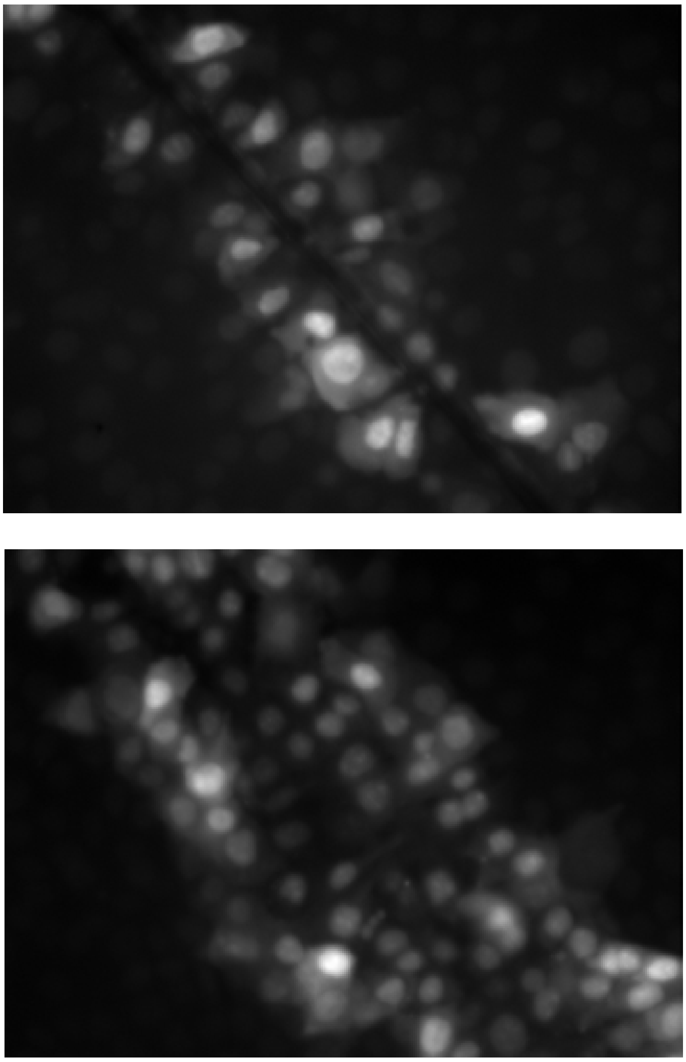

Figure 2: SLDT in a HaCaT monolayer. Top: cells outside of the exposed area; bottom: cells between the electrodes i.e. exposed. The cells that were exposed to the electrical pulses (20 pulses, 100 ns, 10 kV/cm) show a more wide spread distribution of the dye across many cells, indicating enhanced communication activity between cells.

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Degradation of pharmaceutical residues in water (core-funded project)

Problem

Modern pharmaceutical substances are increasingly found in the environment and drinking water due to their persistence to conventional water treatment technologies. Also more advanced processes are challenged (UV treatment is only possible for water with low turbidity; the addition of H_2O_2 is not economically efficient; the use of ozone is limited).

Problem-solving approach

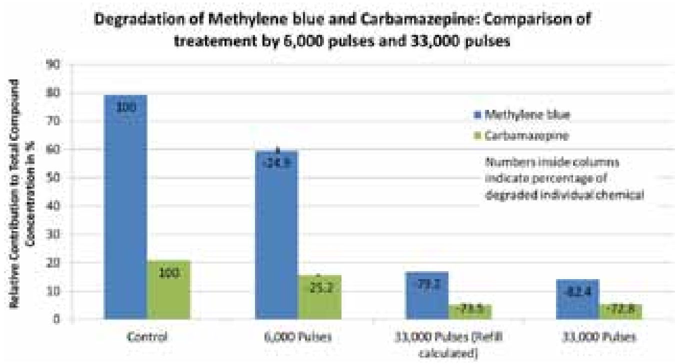
Corona plasmas that are generated by the application of high voltage pulses: streamers can penetrate a large volume of the liquid to be treated and provide highly reactive radical species that are generated from the water itself and can break up residues.

Technological benefits

Main advantages of the approach are: high efficacy for the decomposition of stable compounds; energy efficiency (due to the pulsed operation); no dependency on turbidity; no need for toxic additives (e.g. chlor, hydrogen peroxide).

Results in 2012/13

A robust, modular reactor design was developed that allows for investigations under controlled conditions. Changes in oxygen content, water conductivity, pH-value, and temperature of the solution to be treated can be tracked in real time. The transition from a “batch system” to a “continuous flow system” brought analytical advantages and now also allows the treatment of larger volumes. Initial experiments on the characterization of corona plasmas that were generated for different operating parameters were carried out. Dependencies between conductance of the liquid to be treated, pulse duration and streamer length were identified with respect to guidance for future experiments Selected pharmaceutical residues have been dissolved in water and have been successfully decomposed by the system.



Methylene blue and carbamazepine (an antiepileptic drug) were both dissolved in water and treated in 3 independent trials with 6000 individual discharges (generated with about 10 Hz). Also shown is the endpoint of the experiments after the application of 33000 discharges.

Plans for 2014

- Determining the effectiveness of the reactors against different problematic pharmaceutics
- Measurement and quantification of the hydroxyl radicals that are probably responsible for the key reaction
- Testing of different pulse generators with the aim of increasing effectiveness

Contact

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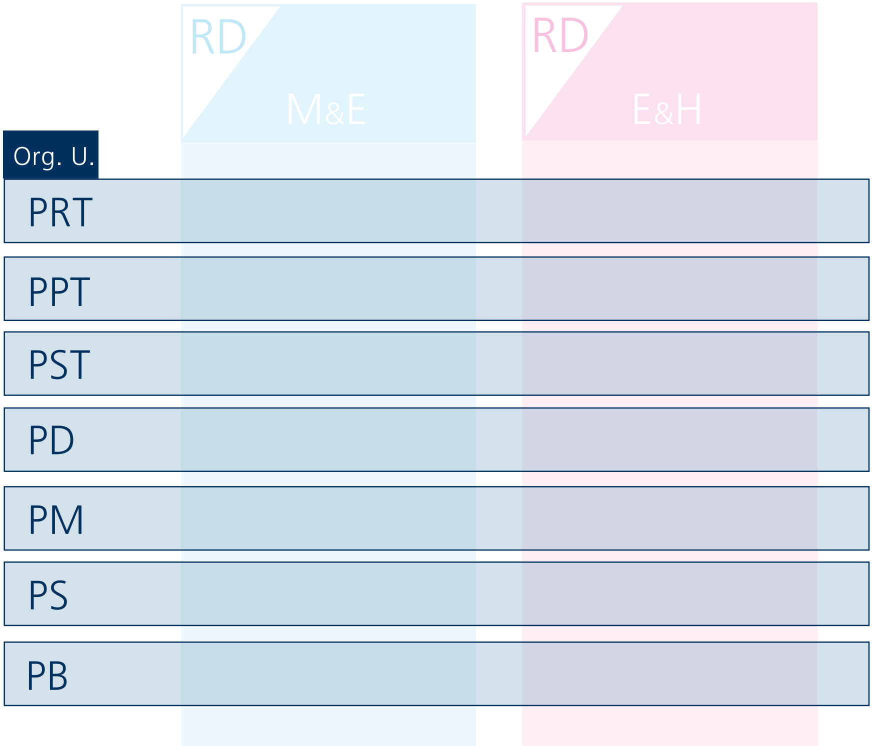


Matrix structure of the Research Divisions (RD) and Scientific Departments (Org. U.)

Research Divisions Plasmas for Materials & Energy

- Research Programme Surfaces / Thin Films
- Research Programme Catalytic Materials
- Research Programme Process Monitoring
- Research Programme Welding / Switching

Research Divisions Plasmas for Environment & Health

- Research Programme Bioactive Surfaces
- Research Programme Plasma Medicine / Decontamination
- Research Programme Pollutant Degradation
- Research Programme Bioelectrics

Scientific Departments

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

Plasma Radiation Technology

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. Currently, a laboratory is being set up for experimental investigations of switching arcs together with the establishment of the required expertise in electrical engineering.
Methods of optical emission spectroscopy will be improved and completed by diode laser 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.

Plasma Process Technology

Key aspects

- Modification and synthesis of catalytically active materials, particularly photosensitization of semi-conductor surfaces for regenerative hydrogen production
- Fixation of catalysts on surfaces
- Nanocomposite films
- Synthesis of adsorbents

Work objectives

- Plasma-assisted processes for surface treatment of small-scale materials (powders, granules, fibres)
- Substrates with thin layers (semi-conductor films)
- Photo- and electro-catalytically active surfaces
- Probes for the measurement of the energy flux on substrates in plasma reactors

Work equipment

- Low pressure and atmospheric pressure plasmas and magnetron sputter sources combined with system for the fluidization of particles
- Plasma diagnostics, energy inflow measurements
- Diagnostics of surfaces with atomic fource microscope, Brunauer-Emmet-Teller method, thermodesorption and contact angle measurement devices
- Photo and electrochemical characterization methods
- Particle size measurements

Medium-term focuses

- Development of photoactive catalyst surfaces and electrode catalysts for solar water splitting
- Development of metal-polymer composite films
- Development of chemical sensors
- Synthesis of new dielectric materials for capacitors
- Development of adsorbers 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 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.

Plasma Surface Technology

Key aspects

- Plasma functionalization and coating of surfaces
- Refinement of plastics, metals, glasses and composite materials
- Control of plasma enhanced deposition processes
- Coatings for controlling the interaction with biological systems
- Ion-assisted production of optical films

Work objectives

- Plasma-assisted processes for the control of interface properties
- Plasma- and ion-assisted processes for the development of functional thin films on plastics, bio-materials and composites with planar as well as 3D geometry
- Investigations on processes and surface / film properties in combination with the respective technology

Work equipment

- Several process systems with low pressure and atmospheric pressure plasmas
- Several application-oriented plasma process systems for the industry-oriented running of Plasma Enhanced Chemical Vapour Deposition (PECVD), Physical Vapour Deposition (PVD), Plasma Immersion Ion Implantation (PIII) and Plasma Ion Assisted Deposition (PIAD), also with higher number of units
- A multi-reactor system, coupled with a clean room, for examinations under defined, most pure environmental conditions with simultaneous access for plasma and process diagnostic processes
- Process monitoring by plasma diagnostics e.g. spectroscopy and probes
- Surface and film analytics for the determination of chemical structure, topology and optical properties, among other, highly resolved scanning X-ray Photoelectron Spectroscopy (XPS), in-situ XPS, infrared Attenuated Total Reflectance (ATR) microscopy, atomic force (ATM), scanning tunnel (STM), scanning electron microscopy (SEM) with Energy Dispersive X-ray (EDX) and 3D visualization, digital optic microscopy, ellipsometry, spectral photometry

Medium-term focuses

The focus of work will be on the investigation of plasmas processes for film optics and for the deposition of thin functional surfaces based on organo-silicon compounds. Furthermore, plasma-chemical surface functionalization will be examined for applications in biomedical technology. The Department is increasingly emphasizing normal pressure plasma processes for surface treatment, and 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 optics, semiconductor technology, biomedical engineering or microsystem technology. The subjects offer potential to produce functional films under atmospheric pressure so that applications such as passivation film systems for complex (3D) components (e.g. sensors), corrosion protection films, barrier films, films for selective release of active substances, coatings for the control of wettability and antimicrobial effective coatings are possible both locally and for difficult-to-reach geometries (such as edges, cavities).
A significantly more selective and density-controllable production of covalent bonds on any material surfaces would be a breakthrough to a new level of quality in plasma-assisted surface modification processes.
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.

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 arc and jet plasmas
- Kinetic description of charge carriers in non-thermal plasmas
- Plasma chemistry and radiation transport
- Interaction of plasmas with walls and surfaces

Work objectives

The Scientific Department deals with the theoretical description and analysis of technologically and scientifically relevant low temperature plasmas. Accordingly, both non-thermal and thermal plasmas are examined. To numerically model these plasmas adequately, it is necessary

- to develop an appropriate plasma model
- to formulate hydrodynamic and kinetic equations, respectively, for the species of the plasma and to couple them with equations for the electric and magnetic field
- to search and evaluate atomic data
- to develop appropriate numerical methods for the solution of the resulting system of differential equations and to use commercial software packages, respectively
- to determine solutions for selected parameter ranges as well as
- to visualize and interpret the results.

The complexity of the complete description requires that partial problems such as the kinetic description of individual plasma components, the treatment of radiation transport and the analysis of spectra are treated separately.

Work equipment

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

Medium-term focuses

The focus of the Scientific Department over the medium term 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,
- the energy dissipation caused by collision and radiative processes,
- the particle and energy transport processes in the plasma,
- the electric and magnetic fields occurring in the plasma, and
- the interaction of individual species with walls and surfaces.

Technological benefits

The research on 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. On the basis of extensive parameter studies, the model calculations make a systematic optimization of technological plasmas possible, e.g. with regard to the electric power input of process plasmas and the plasma chemical process control for surface processing and pollutant degradation. Predictive models for the simulation of switching devices can substantially reduce the expenses for the design and development of switchgears. Such models also support the optimization of the design and operating conditions of plasma torches in joining technology and for surface treatment. The analysis of micro-discharges in dielectric barrier discharges aims at the generation of stable and well-defined atmospheric pressure plasmas for industrial applications. The modelling of capacitively coupled RF atmospheric pressure plasma jets contributes to the improvement of the uniformity of the deposited thin films.

Scientific Department for Plasma Sources

Key aspects

Development, characterization / diagnostics of atmospheric pressure plasma sources for applications for research and development, such as e.g. for biomedical procedures and processes, gas and water treatment as well as surface modification

Work objectives

The Scientific Department's task is to support both Research Divisions 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 biologically and chemically polluted water

The additional focus is the fundamental characterization of the operating parameters as well as the study of the physical mechanisms of the different plasma sources. The impact of plasma treatments on cells, biological tissues (e.g. skin) and organisms is evaluated in cooperation with the Bioengineering Department.

Work equipment

- Development laboratories for atmospheric pressure plasma sources including high voltage power supplies and high voltage metrology, thermal and spectroscopic characterization
- Diagnostics of plasma dynamics with streak- and ultra-fast Intensified Charge-Coupled Device (ICCD) cameras
- Laboratory for "Experimental Plasma Medicine"
- Application laboratory for "Pollutant Degradation"
- Micro-discharge measurement setup with time-correlated individual photon counting and far-field ICCD
- Diagnostics of plasma chemical reactions products using e.g. Fourier Transform Infrared spectroscopy (FTIR) and Flame Ionisation Detection (FID)

Medium-term focuses

The characterization of plasma sources by means of electric and spectroscopic diagnostics, in particular the micro-discharge diagnostics in non-thermal atmospheric pressure plasmas, will be on focus point in the medium-term. In the development and optimization of plasma sources emphasis will be placed on exhaust gas and exhaust air treatment, drinking water and wastewater treatment as well as biomedical applications. Application oriented studies are planned for pollutant degradation in gases and liquids (e.g. by mobile units for field tests) and other issues where the interaction of plasmas with liquids and cells play a dominant role.

Technological benefits

Atmospheric pressure plasmas have become a greater focus of technical applications due to their technical advantages (no vacuum technology, linear process). For new applications such as plasma medicine and chemical and microbial decontamination of air and liquids, the further detailed study of discharge phenomena and operation of plasma sources at atmospheric pressure is even indispensable. The applications always require the development of the plasma sources adapted to the respective task and the characterization of the working and operating parameters.

Plasma Bioengineering

Key aspects

- Study and development of methods for plasma decontamination for medical devices, packaging and food
- Investigation of the interaction of plasma and fluids, as well as their effect on micro-organisms and biofilms particularly for plasma medicine
- Development of process diagnostics and high-frequency technology

Work objectives

- Microbiological assessment of plasma processes in particular for issues of plasma medicine and decontamination
- Development of specific plasma sources and processes for decontamination in food and medical applications on the basis of atmospheric pressure plasma sources, particularly microwave-excited plasmas
- Development of reversible antimicrobial coating systems based on nanoparticles
- 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 characterisation of microwave sources e.g. for plasma-based sensors for speciation analytics

Work equipment

- Microbiological laboratories of biosafety level S2
- 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)
- 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 and cell-biology
- Support of the development of methods in plasma medicine and plasma pharmacy e.g. new methods for wound healing
- Development and analysis of reactors and processes for plasma cleaning and decontamination in food, 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
- Establishment of the microbiology standards for plasma medical treatments and decontamination

Technological benefits

The targeted use of methods in plasma decontamination can open up new possibilities in food hygiene in the tension atmosphere between increasing globalization of trade flows and the increase in safety expectations for food hygiene. New technologies in the antimicrobial treatment of medical devices can help to reduce risks with an ageing society.
The area of experimental plasma medicine, initially demonstrated in the example of wound healing, is increasingly showing additional application possibilities that could start to be used in the development of new medical devices. Lacking standards must be developed independently of sectors and with a broad consensus.

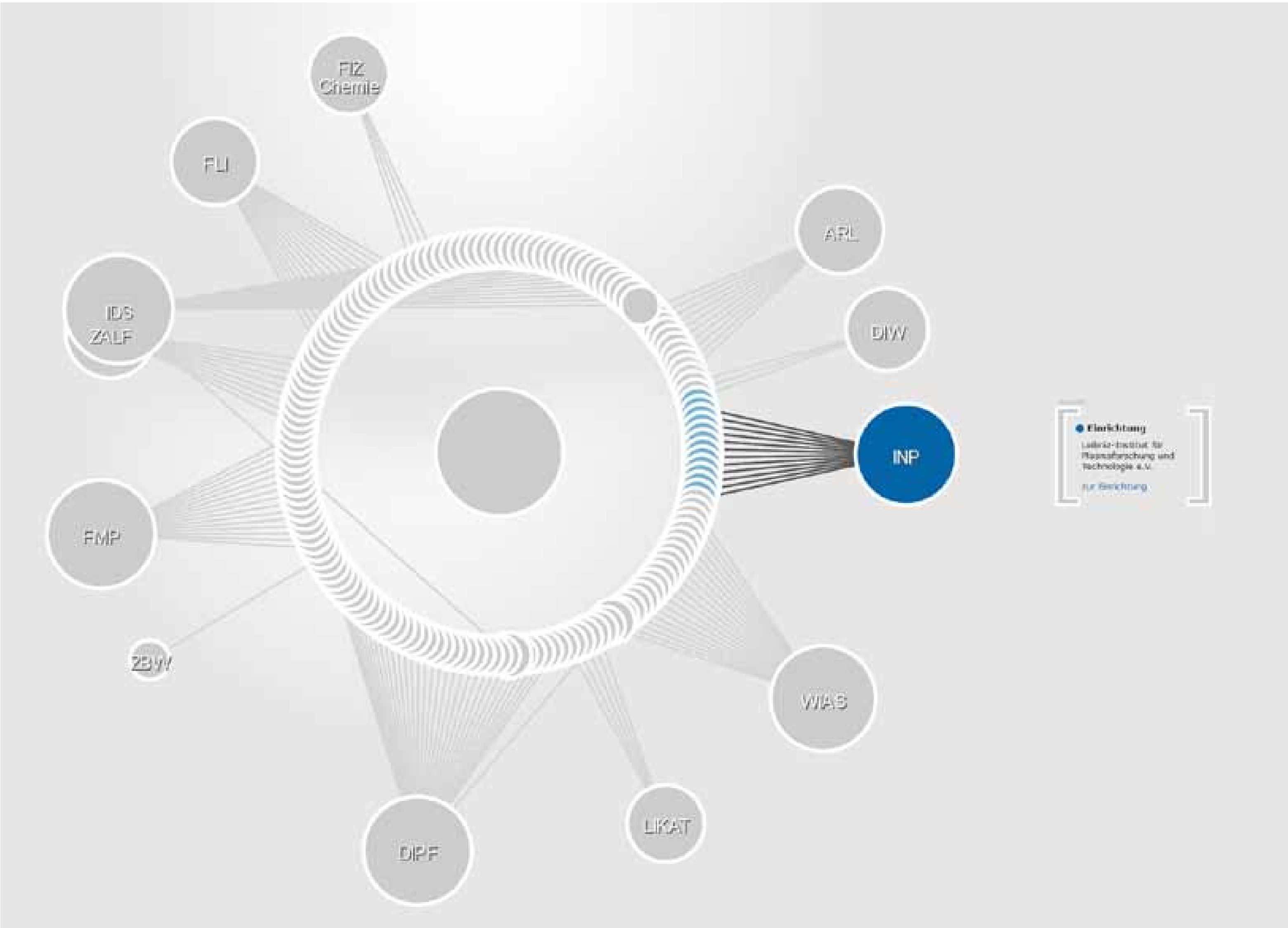
MANAGEMENT SUPPORT & MARKETING

Fields of activity

- Acquisition and execution of public funded projects
- Preparation, submission and quality assurance of project proposals
- Project management and controlling
- Search for suitable cooperation partners consortium building in economy and science
- Contract and intellectual property rights management
- Support in knowledge transfer
- Review and distribution of public calls for equipment-tenders (internal)
- Network management and lobbying
- Marketing and public relations management for selected projects
- Distribution of scientific information
- Supporting Boards

Competencies

- Many years of experience in the formulation and design of project applications
- Knowledge of suitable sources of funding opportunities and their respective programmes
- Intensive expertise for identification and formulation of project ideas
- Know-how of the entire application spectrum
- Legal and economic expertise (contracts, patents, calculation, controlling)
- Professional network management (initiation and management of cooperations, identification of specific topics)
- Raising visibility of the Institute among sponsors, funding agencies and policy makers



Medium-term objectives

- Increase of public and industrial funding
- Professionalization of processes and project management (internal)
- Increase the visibility of the INP in the funding community
- Intensify networking efforts of the INP on the national and international funding environment, as well as with industry and society in general
- Improve the patent licensing strategies

Research Management's contribution to the structural development

The Research Management is in particular responsible for the administrative and organizational support of the research activities as well as the public image of the institute. Due to this range of activities that are being covered by the research management, the scientists are able to focus on their core competences in the respective research fields. The research management of the INP considers that it's an active and efficient service provider and acts in close cooperation with the management and the departments or the project managers, respectively.

In the science and funding community the INP acts as an advocate of plasma technology overall. The interest of public-sector funding is justified by both the scientific-intellectual challenge and its economic potential at the INP. Already in the run-up to specific call for proposals, the early integration of plasma technology is essential. The INP acts as a supporter for the implementation of individual initiatives within the Plasma Community with the help of the Research Management. Controlling and managing projects are very important, especially in industry cooperations.

INP's administrative service for scientists is being constantly developed and strategically expanded for forming alliances and strategic partnerships.

Projects

KNOWLEDGE EXPLOITATION

With the project "Knowledge Exploitation (WV²)", an extended exploitation concept for the transfer of INP's knowledge is developed. The aim is to distinguish scientific knowledge as an independent, valuable competency. A concept is being developed with a view to organizational assignments, processes, suitable project methodology skills and legal certainty. In order to increase the attention given to the subject of plasma physics, an exhibition for the plasma physics exhibit in 2014 is prepared in the framework of the Science Center Phänomenta in Peenemünde, . In addition, a generally understandable film about plasma medicine will be shot, emphasizing INP's leadership role and making it accessible on *www.youtube.com.*

Funding: Federal Ministry of Education and Research (BMBF)

Bundesministerium für Bildung und Forschung

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)".

Europäische Fonds EFRE, ESF und ELER in Mecklenburg-Vorpommern

Mecklenburg Vorpommern

Ministerium für Bildung, Wissenschaft und Kultur

PLASMASHAPE

The project "PlasmaShape" is funded by the 7th Framework Program (REG-POT capacities) of the European Commission and its goal is to reinforce the scientific core competencies of INP (see also page 16).

Funding: European Commission

SEVENTH FRAMEWORK PROGRAMME

Europäische Kommission

INTERNATIONAL CONTACTS

In order to integrate INP even better in the international research community, different preparatory measures have been undertaken with partners in the United States, Russia, the Baltic Sea States and Vietnam. Accordingly, it has been possible to develop a resilient network with partners for future bilateral and public funded European projects.

Funding: International Bureau of the German Federal Ministry for Education and Research

Bundesministerium für Bildung und Forschung

Internationales Büro des BMBF

Research marketing and public relations

The research-supporting marketing at INP makes its contribution especially to the systematic advance planning an budget management of advertising and marketing activities, their coordination and control. In addition, internal and external communication with employees plays and important role in the daily work (e.g. internal employee, newspaper INPapier), customers, cooperation partners, interest associations and state bodies, inculding reporting and tracking. The organization of internal events (e.g. light lecture or girls' day), scientific meetings, workshops or trade fair appearances complement the tasks of the research-supporting marketing and public relations work. Other marketing-oriented tasks include the setting and printing of scientific posters, the preparation of presentations, illustrations, graphics and 3D animations as well as the design of brochures or flyers or the creation, refinement and maintenance of INP and other project-related websites.

Administration

An essential complement and form of organizational support for the scientific departments and groups is INP's „Administration" department. It primarily organizes smooth operations. Both areas - administration and infrastructure - are designed to be streamlined.

The Institute's Department of Administration / Infrastructure covers 4 areas: human resources, finance/controlling (with purchasing, accounting, equipment and external funding management and travel expenses), infrastructure and IT. The area of infrastructure consists of the mechanical workshop, a glass blowing factory and an electronics shop, and also oversees the Institute's building technology, as well as all construction measures. For data processing, INP maintains a data network and further develops and maintains the connection of the INP network to external networks.

To ensure the work and health protection requirements and safety standards, subject-specific officers have been appointed (for hazardous materials, fire protection, electrical safety etc.). The coordination of the activities is carried out by the safety officer, who has the authority to give instructions on behalf of the Board of Directors.

COOPERATIONS

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

- 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 Mathematik und Informatik
  Prof. Kugelmann

- Ernst-Moritz-Arndt-Universität Greifswald
  Institut für Physik
  Prof. Hippler, Prof. Meichsner, PD Dr. Wagner, Dr. Wulff, PD Dr. Bronold, Jun Prof. Stollenwerk

- Ernst-Moritz-Arndt-Universität Greifswald
  Institut für Physik, Bereich Angewandte Physik
  Dr. Salewski

- Ernst-Moritz-Arndt-Universität Greifswald
  Universitätsrechenzentrum
  Prof. Schneider

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

- Ernst-Moritz-Arndt-Universität Greifswald
  Klinik und Poliklinik für Mund-Kiefer-Gesichtschirurgie/ Plastische Operationen
  OA Dr. Kindler

- Ernst-Moritz-Arndt-Universität Greifswald
  Institut für Medizinische Biochemie und Molekularbiologie
  Prof. Dr. rer. nat. habil. Walther

- Ernst-Moritz-Arndt-Universität Greifswald
  Institut für Pharmazie
  Prof. Lindequist, PD Dr. Haertel

- Ernst-Moritz-Arndt-Universität Greifswald
  Institut für Pharmakologie
  Prof. Siegmund
  WK Centifluidic

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  Institut für Biochemie
  Dr. Vock, Dr. Kahlert

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  Dr. Kindermann

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  Friedrich-Loeffler-Institut für Medizinische Mikrobiologie
  Prof. Steinmetz

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  Prof. Völzke

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  Prof. Jünger

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  Zentrum für Zahn-, Mund- und Kieferheilkunde
  Prof. Kocher

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  Klinik und Poliklinik für Chirurgie
  Prof. Ekkernkamp, Dr. Hinz, PD Dr. v. Bernstorff, Dr. Partecke

- Fachhochschule Stralsund
  SIMAT (Stralsund Information Management Team)
  Prof. Klotz

- Fachhochschule Stralsund
  Fachbereich Elektrotechnik und Informatik
  Prof. Wetenkamp

- Fachhochschule Stralsund
  Fachbereich Maschinenbau
  Prof. Rossmanek

- Fachhochschule Stralsund
  Fachbereich Elektrotechnik und Informatik
  Prof. Luschtinetz

- Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik (FBH), Berlin
  Dr. Gesche

- Forschungszentrum Wismar
  Prof. Wienecke

- Fraunhofer-Center für Nanoelektronische Technologien, Dresden
  Dr. Uhlig

- Fraunhofer-Institut für Angewandte Optik und Feinmechanik, Jena
  Optische Schichten
  Prof. Kaiser

- Fraunhofer-Institut für Elektronische Nanosysteme, Chemnitz
  Abteilung Back-end of Line
  Prof. Schulz

- Fraunhofer-Institut für Fertigungstechnik und Angewandte Materialforschung, Bremen
  Dr. Lommatzsch

- Fraunhofer-Institut für Schicht- und Oberflächentechnik, Braunschweig
  Dr. Sittinger, Dr. Pflug

- Fraunhofer-Institut für Verfahrenstechnik und Verpackung, Freising
  Lebensmittelqualität
  Dr. Muranyi

- Fraunhofer-Institut für Werkstoff- und Strahltechnik, Dresden
  Dr. Mäder

- Georg-August-Universität Göttingen, Universitätsmedizin
  Abteilung Dermatologie, Venerologie und Allergologie
  Prof. Emmert

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1. Harhausen, J.; Foest, R.; Ohl, A.; Steffen, H.: **Charakterisierung von Plasmaprozessen zur ionengestützten Abscheidung (PIAD) von optischen Schichten.** DPG-Frühjahrstagung, Stuttgart/Germany 2012

2. Hoder, T.; Höft, H.; Kettlitz, M.; Cernak, M.; Brandenburg, R.: **High-resolution measurements on barrier and corona discharges: a tracing of streamers.** Potential & Appl. of Surf. Nanotreat. of Polym. & Glass, Brno/Czech Rep. 2012

3. Hoder, T.; Kettlitz. M.; Höft, H.; Weltmann, K.-D.; Brandenburg, R.: **Comparison of pulsed and sinusoidal operated barrier discharges.** 21st ESCAMPIG, Viana do Castelo/Portugal 2012

4. Loffhagen, D.: **Modelling of nonthermal atmospheric-pressure plasma applications.** Gordon Res. Conf. Plasma Processing Sci., Smithfield/USA 2012

5. Masur, K.: **Influence of Non-Thermal Plasma on Human Cell Activities** Cost Action Bio-Plasma MP1101, Dublin/Ireland 2012

6. Polak, M.; Finke, B.; Quade, A.; Fricke, K.; Hempel, F.; Zietz, C.; Bader, R.; Nebe, J.B.; Foest, R.; Weltmann, K.-D.: **Plasma assisted surface engineering for biomedical applications.** 1st Young Professionals Workshop on Plasma Medicine, Boltenhagen/Germany 2012

7. Reuter, S.: **Controlling reactive component output of atmospheric pressure plasmas in plasma medicine.** Cost Action Bio-Plasma MP1101, Dublin/Ireland 2012

8. Reuter, S.: **plasmatis Center for Innovation Competence: Controlling reactive component output of atmospheric pressure plasmas in plasma medicine.** 65th GEC, Austin, Texas/USA 2012

9. Reuter, S.; Winter, J.; Hammer, M.; Masur, K.; Wende, K.; Tresp, H.; Schmidt-Bleker, A.; Duennbier, M.; Hänsch, M.; von Woedtke, Th.; Weltmann, K.-D.: **Measurement, Modelling, and Controle of the Reactive Species Composition in the Effluent of an Argon Plasma Jet.** 39th ICOPS, Edinburgh/UK 2012

10. Röpcke, J.; Davies, P. B.; Glitsch, S.; Hübner, M.; Lang, N.; Lopatik, D.; Nägele, M.; Rousseau, A.: **Applications of MIR-Laser Systems for Plasma Diagnostics and Trace Gas Detection in Basic Research and Industry.** ACP, Guangzhou/China 2012

11. Schnabel, U.; von Woedtke, Th.; Weltmann, K.-D.: **Standardization of experimental procedures for plasma-based biodecontamination - problems and solutions.** Cost Action Bio-Plasma MP1101, Dublin/Ireland 2012

12. Schwock, A.: **Transnational projects - a possibility to finance Russian-German cooperation.** 4. Russisch-Deutsche Konferenz, Tomsk/Russland 2012

13. von Woedtke, Th.: **Plasma-cell interaction mechanisms.** 39th ICOPS, Edinburgh/UK 2012

14. von Woedtke, Th.; Oehmigen, K.; Hänsch, M.A.Ch.; Weltmann, K.-D.: **Plasma Pharmacy: The Use of Plasma-treated Products for therapeutic Purposes.** 4th ICPM, Orleans/France 2012

15. Weltmann, K.-D.: **Characterization of Plasma Sources in Life Science.** MRS Spring Meeting, San Francisco/USA 2012

16. Weltmann, K.-D.: **Recent development of plasma sources for applications in life science.** CEITEC Int. Conf., Brno/Czech Republic 2012

17. Winter, J.; Dünnbier, M.; Iseni, S.; Schmidt-Bleker, A.; Weltmann, K.-D.; Reuter, S.: **Messung von Ozon in Atmosphärendruckplasmen.** 14. AK-ADP, Bochum/Germany 2012

18. Zhuang, J.; White, J. A.; Jing, Y.; Joshi, R. P.; Kolb, J, F.: **Dielectric Characteristics of Mammalian Cells During and After Exposure to Nanosecond Pulsed Electric Fields (nsPEF).** Int. Workshop "Membranes in Health and Disease", Gomadingen/Germany 2012

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1. Baeva, M.; Uhrlandt, D.; Gorchakov, S.: **Collisional-radiative modeling of a free-burning arc plasma in argon.** 40th ICOPS and 19th PPC (PPPS 2013), San Francisco/California 2013

2. Brandenburg, R.: **Dielectric Barrier Discharges: Pulsed Breakdown, Electrical characterization and Chemistry.** 40th ICOPS and 19th PPC (PPPS 2013), San Francisco/California 2013

3. Brandenburg, R.: **Abgasbehandlung mit Plasmen: Stand und Ausblick.** 16. Fachtagung Plasmatechnologie, Greifswald/Germany 2013

4. Finke, B.; Testrich, H.; Rebl, H.; Nebe, B.; Bader, R.; Walschus, U.; Schlosser, M.; Weltmann, K.-D.; Meichsner, J.: **Anti-adhesive finishing of temporary implant surfaces by a plasma-fluorocarbon-polymer.** THERMEC, Las Vegas/USA 2013

5. Harhausen, J.; Foest, R.; Ohl, A.; Gäbler, D.; Kaiser, N.; Stenzel, O.;Brinkmann, R.-P.; Schröder, B.; Storch, R.; Styrnoll T.: **Diagnostik und Steuerung von PIAD-Prozessen.** DPG-Frühjahrstagung Plasmaphysik, Jena/Germany 2013

6. Kersten, H.; Schneider, V.; Basner, R.; Schubert, G.; Wolter, M.; Haass, M.; Trottenberg, T.; Fehske, H.: **Micro Particles as Plasma Probes.** 31st ICPIG, Granada/Spain 2013

7. Loffhagen, D.: **Impact of small molecular admixtures on the electron drift velocity in argon.** 19th SAPP Conf., Vratna/Slovakia 2013

8. Masur, K.; Wende, K.; Schmidt, A.; Hasse, S.; Barton, A.; Bundscherer, L.; Bekeschus, S.: **Cold atmospheric pressure plasmas in Biology and Medicine - from basic research to application.** 3rd Int. Symp. for Plasma Biosciences, Jeju/Korea 2013

9. Reuter, S.; Winter, J.; Tresp, H.; Dünnbier, M.; Schmidt-Bleker, A.; Séni, S.; Hammer, M.; Weltmann, K.-D.: **Feed Gas Humidity Versus Ambient Humidity - What Matters More in Plasma Medicine and What Makes Cells Care?.** 40th ICOPS and 19th PPC (PPPS 2013), San Francisco/California 2013

10. Röpcke, J.: **On recent progress in monitoring of technological plasmas.** 16. Fachtagung Plasmatechnologie, Greifswald/Germany 2013

11. Röpcke, J.; Hamann, S.; Hübner, M.; Lang, N.; Lopatik, D.; van Helden, J. H.: **On recent progress in studying plasma chemical phenomena using infrared absorption techniques.** 5th Central Eur. Symp. on Plasma Chemistry, Balatonalmadi/Hungary 2013

12. Schäfer, J.: **Temperature diagnostics of a non-thermal plasma jet at atmospheric pressure.** 66th GEC, Princeton/USA 2013

13. Schwock, A.; Kolb, J.: **New approach for combined plasma based technologies for waste water treatment.** IAEA Techn. Meet., Vienna/Austria 2013

14. Sigeneger, F.; Schäfer, J.; Foest, R.; Loffhagen, D.; Weltmann, K.-D.: **Modellierung eines rf-angeregten Plasmajets.** DPG-Frühjahrstagung Plasmaphysik, Jena/Germany 2013

15. Uhrlandt, D.; Gött, G.; Kozakov, R.; Methling, R.; Franke, St.; Baeva, M.; Schöpp, H.; Schein, J.; Bachmann, B.: **Study of radiation of high pressure arcs.** 20th Symp. on Physics of Switching Arc, Brno/Czech Republic 2013

16. van Helden, J. H.; Lang, N.; Röpcke, J.: **Cavity-enhanced absorption spectroscopy: Transition from UV/VIS into the MIR using quantum cascade lasers.** 16th LAPD, Madison/USA 2013

17. von Woedtke, Th.; Weltmann, K.-D.: **Plasma sources for plasma medicine: basic requirements for physical and biological characterization.** JSAP MRS Joint Symposia, Kyoto/Japan 2013

18. von Woedtke, Th.; Weltmann, K.-D.: **Physical plasmas for medical application: State and persepctives 2013.** 16. Fachtagung Plasmatechnologie, Greifswald/Germany 2013

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2. Wiese, R.; Bartsch, R.:
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3. Schöne, A.; Fischer, J.; Schröder, K.; Steffen, H.; Besch, W.; Vogelsang, A.; Weltmann, K.-D.; Nebe, B.:
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4. von Woedtke, Th.; Stieber, M.; Krafczyk, S.; Weltmann, K.-D.; Brandenburg, R.:
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5. Horn, S.; Foest, R.; Stieber, M.; Weltmann, K.-D.; Schäfer, J.; Brandenburg, R.:
Device and method for producing a cold, homogeneous plasma under atmospheric pressure conditions, PCT/EP2012/059939, WO 2012163876 A1

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2. Müller, S.; Krüger, T.; Mleczko, Norman; Weltmann, K.-D.; Zahn, R.-J.; Reich, W.; Anklam, K.; Harfenstein, I.; Koburger, T.; Neudeck, D.:
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3. Stieber, M.; Ehlbeck, J.;
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4. Weltmann, K.-D.; Krömker,
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5. Kolb, J.; Banaschik, R.; Zhuang, J.:
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4. von Woedtke, Th.; Stieber, M.; Weltmann, K.-D.; Wilke, Ch.; Ehrenberg, U.: **Plasma Device for Selective Treatment of Electropored Cells, EP 2254664 A1**
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1. Fricke, Katja
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2. Vogelsang, Andreas (Beschäftigter INP, jedoch nicht mehr zum Ende der Promotion hin)
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3. Chen, Hsin-Hung (kein Beschäftigter INP)
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4. Hübner, Marko
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5. Nastuta, Andrei Vasile (kein Beschäftigter INP)
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6. Becker, Markus
"Hydrodynamische Modellierung anisothermer Plasmen"
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1. Kolipaka, Karthika Lakshmi
„Cobalt - plasma polymerized hexamethyldisilazane nanocomposites prepared by hybrid PVD/PECVD process"
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2. Walter, Christian
"Synthese von elektroaktiven Metall-Polypyrrol-Kompositen als Kathodenkatalysatoren für Brennstoffzellen"
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3. Lopatik, Dmitry
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Toropchin, Artem
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Ziemann, Paul
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Forbrig, Enrico
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Kupsch, Sarah
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Jatsch, Lisa
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Eckroth, Jacqueline
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Jarick, Marcel
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Sep 13

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