P 23: Low Temperature Plasmas

Zeit: Mittwoch 16:30–18:30 Raum: HS Foyer

P 23.1 Mi 16:30 HS Foyer

Kinetic Modeling of the Surface Mode Excitation in CCP Discharges with the Electrostatic and Electromagnetic Field Descriptions — •Denis Eremin, Ali Arshadi, Schabnam Naggary, and Ralf Peter Brinkmann — Institute for Theoretical Engineering, Ruhr University Bochum, Univeristätsstrasse 150, 44801, Bochum, Germany

It has been recently demonstrated that uniformity of the plasma density and ion fluxes impinging on the electrodes in large-scale CCP reactors operated at very high frequencies can be linked to excitation of the surface modes supported by such reactors filled with plasma. There are two types of such modes, which can be distinguished by the physical phenomena associated with them, the plasma-series-resonance (PSR) and the self-bias (SB) modes. In this work excitation of these modes and their influence on the plasma uniformity is investigated by means of self-consistent particle-in-cell/Monte-Carlo (PIC/MCC) simulations in the electrostatic and the electromagnetic limits. In the latter case a novel implicit PIC/MCC energy-conserving approach is employed, which helps to get rid of numerical heating. The particle algorithms of the corresponding codes are massively parallelized on GPU.

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Guide field magnetic reconnection on electron and ion scales — •Adrian von Stechow, Dusan Milojevic, Ilya Shesterikov, Olaf Grulke, and Thomas Klinger — Max-Planck-Institut für Plasmaphysik, Greifswald

Magnetic reconnection is a generic plasma process characterized by the release of accumulated magnetic energy due to rapid changes in magnetic topology. A central feature of reconnection is the formation of a highly localized current sheet on length scales much smaller than those of the externally imposed magnetic field. The detailed properties of this sheet determine the rate at which reconnection proceeds, and the appropriate model description depends crucially on the ordering of plasma length and time scales with respect to those of the current sheet.

VINETA.II is a linear, moderate to high guide field laboratory reconnection experiment that has previously operated in a regime in which ion dynamics play a minor role ($f > f_{ci}$) and for which an electron-MHD model is appropriate. Recent upgrades significantly extend this parameter space into an Alfvénic regime by increasing the time scales at which reconnection is driven and by broadening the current sheet through improved plasma sources. This contribution characterizes the transition between these regimes by interpreting key current sheet parameters such as magnetic flux transfer, current and plasma densities as well as wave propagation velocities.

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Force balance and Ohm's law in the reconnecting current sheet in the VINETA-II magnetic reconnection experiment — •Ilya Shesterikov[1], Adrian von Stechow[1], Dusan Milojevic[1], Olaf Grulke[1] und Thomas Klinger[1,2] — [1]Max Planck Institute for Plasma Physics, 17491 Greifswald, Germany — [2]Institut für Physik, Ernst-Moritz-Arndt Universität Greifswald, Felix-Hausdorff-Straße 6, D-17489 Greifswald

VINETA-II is a linear experiment developed for the study of a driven magnetic reconnection. The global description of the current sheet properties is important to relate magnetic reconnection to the response of the plasma. This includes the three-dimensional (3D) estimate of the diamagnetic current, the Lorenz force and $\vec{E} \times \vec{B}$ terms included in the MHD force balance equation. A 3D positioning system equipped with a fast swept Langmuir probe and B-dot probe is used. These two probes together provide a complete set of quantities required in the analysis: n_e, T_e, ϕ_{fl}, ϕ_p - from the Langmuir probe and $\vec{B}$ from the B-dot probe. $\vec{E}$ is evaluated on the base of the spatial distribution of ϕ_p. Within the frame of global description one addresses the key question which terms in the generalized Ohm's law have a major influence on the evolution of magnetic reconnection. The previous 2D estimate of the in-plane MHD force balance showed that the $\vec{E} \times \vec{B}$ term plays a significant role. In the present work we present a full 3D estimation, without the assumption on the axial homogeneity.

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Plasma formation in the KATRIN tritium source — •Laura Kuckert — for the KATRIN collaboration, KIT, Karlsruhe, Germany

The Karlsruhe Tritium Neutrino Experiment (KATRIN) aims to measure the neutrino mass with a sensitivity of 200 meV/c^2 (90% C.L.) in a direct approach using the beta decay of molecular tritium. The neutrino mass is extracted from a fit of modelled beta decay spectra to the measured electron spectrum. Hence, it is important to consider all effects that impact the electron energy. The potential energy of the emitted electrons is set by the electrostatic potential at the position of beta-decay in the windowless gaseous tritium source (WGTS). The potential distribution in the WGTS is determined by a cold low-density plasma that forms inside the strong magnetic field of the WGTS through beta decay and secondary ionizations. To understand the formation and structure of the plasma potential, a comprehensive fluid plasma model has been developed that includes the creation, annihilation and motion of electrons and ions as well as neutral gas flow. The results of the plasma modelling are reviewed with regard to different surface conditions and a monitoring option for the potential distribution is presented that uses monoenergetic electrons from ^{83m}Kr. Implications on the systematics budget for the neutrino mass measurement are inferred. Supported by BMBF (05A14VK2), HAP and the Helmholtz Association.

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Single self-stabilized filament in plane-parallel barrier discharge configuration: existence regimes, breakdown mechanism, and memory effects — •Robert Tschiersch, Sebastian Nemschokmichal, and Jürgen Meichsner — Institute of Physics, University of Greifswald, Felix-Hausdorff-Str. 6, 17489 Greifswald

This contribution reports on a single filament which is self-stabilized in the plane-parallel barrier discharge configuration. The discharge is operated inside a gap of 3 mm shielded by glass plates on both electrodes, using helium-nitrogen mixtures and square-wave feeding voltage at a frequency of 2 kHz. The combined application of electrical measurements, ICCD camera imaging, optical emission spectroscopy, and surface charge diagnostics allowed to study the correlation between volume and surface processes during the discharge development. Priority is given to the formation conditions, breakdown mechanism, and underlying memory effects. Therefore, the existence regimes were investigated by systematic variation of the nitrogen admixture to helium, the total pressure, and the feeding voltage amplitude. In each case, the single self-stabilized discharge filament is obtained by significant reduction of the voltage amplitude after the discharge ignition in the multi-filament regime. Here, the outstanding importance of the surface-charge memory effect for the long-term stability is pointed out by the calculation of the spatio-temporally resolved gap voltage. The optical emission from the discharge reveals characteristics that are partially reminiscent of both the glow-like barrier discharge and the microdischarge regime.

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Inactivation of *Enterococcus mundtii* by Indirect Plasma Treatment using Surface Micro-Discharge Electrode — •Sandra Moritz[1], Janine Mandler[1], Sylvia Binder[2], Tetsuji Shimizu[2], Meike Müller[3], Markus H. Thoma[1], and Julia Zimmermann[2] — [1]I. Physikalisches Institut, JLU Gießen, Germany — [2]terraplasma GmbH, Garching, Germany — [3]DLR Oberpfaffenhofen, Germany

Inactivation of microorganism by CAP is one major application in the field of plasma medicine. In this contribution, the inactivation of bacteria by an indirect plasma treatment using a Surface Micro-Discharge electrode is discussed. This could be used for e.g. disinfection of dental equipment. The experimental setup consists of a SMD electrode in a box, a chamber for samples, a humidifier (optionally) and a pump. A voltage of 6.4 kVpp at 10 kHz was applied to the electrode and the power consumption was around 3.5 W. By the pump a plasma gas flow is circulated from the electrode to the treatment chamber, through the humidifier and back to the pump. The plasma gas is confined in the system. Bacterial samples were prepared on stainless steel plates using *Enterococcus mundtii*. Each had approximately 10^6 bacteria. They were placed in the chamber and treated for 1-15 min.

Until 5 min in treatment time, there is a relatively fast inactivation effect with D-value (1 log reduction) of 1.5 min. After 5 min, the inactivation effect becomes slower. In 15 min, a larger than 5 log reduction of bacteria could be achieved. In the conference, time evolution of reactive species and mechanism of bactericidal effect will be discussed.

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Experimentelle Untersuchung der Streamerpropagation und Entladungsentwicklung auf dielektrischen Oberflächen — •Manfred Kettlitz, Rouven Klink, Hans Höft und Ronny Brandenburg — INP Greifswald, Felix-Hausdorff-Straße 2, 17489 Greifswald

Untersucht wurde das Ausbreitungsverhalten von Mikroentladungen auf einer Keramikoberfläche in Stickstoff-Sauerstoff-Gasgemischen bei Atmosphärendruck. Um die Entladungsentwicklung auf die Oberfläche zu begrenzen, wurde eine Anordnung mit direkt auf dem Dielektrikum anliegenden Nadelelektroden verwendet. Die Entladungen wurden mit einer unipolaren gepulsten Rechteckspannung mit variabler Amplitude und 4,3 kHz Wiederholfrequenz betrieben. Der Zündvorgang sowie die Entladungsausbildung auf der Oberfläche wurden durch schnelle ICCD-Kameras und eine Streakkamera beobachtet. Während in Einzelaufnahmen eine ungleichäßige und verzweigte Struktur der Entladungskanäle sichtbar wird, zeigt die Akkumulation über mehrere Entladungen eine konzentrische Propagationsfront, die von der Spitze der Nadelelektrode ausgeht. Je nach Polarität der metallischen Elektrode im Vergleich zum umgebenden Dielektrikum zeigen sich sowohl Unterschiede in der Ausbreitung der Entladung als auch in deren Propagationsgeschwindigkeit. So entwickelt sich bei positiver Polarität der metallischen Elektrode (steigende Flanke des HV-Pulses) ein positiver Streamer mit wesentlich größerer Ausbreitungsgeschwindigkeit ($5 \cdot 10^5 \frac{m}{s}$) als bei negativer Polarität (fallende Flanke des HV-Pulses).

P 23.8 Mi 16:30 HS Foyer

Direct determination of electron phase trajectories in striated inert gas discharges — •Yuri B. Golubovskii[1], Sergey Valin[1], and Florian Sigeneger[2] — [1]St. Petersburg State University, Universitetskaya St. 7/9, 199034 St. Petersburg, Russia — [2]INP Greifswald, Felix-Hausdorff-Str. 2, 17489 Greifswald

A new dynamic method to analyse resonance effects in striated glow discharge plasmas is proposed as a supplement to kinetic approaches. The method is applicable to striations which are caused by the nonlocal electron behaviour at lower pressure and current. It is based on the direct analysis of the electron phase trajectories in spatially periodic fields and avoids the solution of the spatially inhomogeneous Boltzmann equation.

Main aspects of the resonance effects are obtained by studying the electron phase trajectories in strongly modulated electric fields. The relaxation into the established periodic state is demonstrated by varying the initial electron energy. For S, P and R striations, the obtained trajectories very good agree with corresponding results obtained from a kinetic approach. Furthermore, the resonance behaviour in the case of S striations is studied by detuning the period length of the electric field.

P 23.9 Mi 16:30 HS Foyer

Investigations on the dynamics of non-reactive and reactive high-power impulse magnetron sputtering plasmas — •Katharina Grosse, Wolfgang Breilmann, Christian Maszl, Jan Benedikt, and Achim von Keudell — Ruhr-Universität Bochum

High power impulse magnetron sputtering (HiPIMS) is a technique for thin film deposition and can be operated in reactive and non-reactive mode. The growth rate of HiPIMS in the non-reactive mode reduces to 30% compared to direct current magnetron sputtering (dcMS) at same average power. However, the quality of the coatings produced with HiPIMS is excellent which makes these plasmas highly appealing. Target poisoning is occurring in the reactive mode which among other things influences the plasma dynamics and changes the secondary electron emission coefficient. An advantage of reactive HiPIMS is that the sputtering process can be operated hysteresis-free which can result in a higher growth rate compared to dcMS. In this work, thin films are deposited by a HiPIMS plasma which is generated by short pulses of 100 μs with high peak power densities in the range of >1 kW/cm^2. Both Ar and Ar/N_2 admixtures are used to sputter a 2" titanium target. The particle transport from the target to the substrate is analysed with time-resolved ion energy distribution measurements and phase-resolved optical emission spectroscopy. Furthermore, the time-resolved growth rate of the deposited film is investigated. The time- and energy-resolved particle fluxes in non-reactive and reactive HiPIMS plasmas are compared and implications on the sputter process are discussed.

P 23.10 Mi 16:30 HS Foyer

Spatiotemporal evolution of the reconnection current sheet — •Dusan Milojevic[1], Adrian von Stechow[1], Ilya Shesterikov[1], Olaf Grulke[1], and Thomas Klinger[1,2] — [1]Max Planck Insitute for Plasma Physics,17491 Greifswald,Germany — [2]Instituet fr Physik, Ernst-Moritz-Arndt Universitaet Greifswald, Felix-Hausdorff-Str. 6, D-17489 Greifswald

Magnetic reconnection is a process, in which magnetic field lines break up at the magnetic X-point and rearrange, often accompanied by a transfer of magnetic field energy into thermal energy. The plasma response to magnetic reconnection is characterized by the formation of a current sheet in an area around the magnetic X-point, where the magnetic field lines diffuse. The shape of the current sheet has a strong influence on the evolution of reconnection. In the linear VINETA-II experiment the plasma current is provided by an array of plasma guns, which act as an electron source and influence the spatial distribution and amplitude of the reconnection current. The plasma guns can be operated individually which gives the possibility for a variety of initial conditions for the current sheet. In this contribution the spatiotemporal evolution of the reconnection current sheet is studied in dependence of the current source and reconnection drive scheme. Special attention is paid to the response of the current sheet to a spatially inhomogeneous reconnection drive scheme.

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Electronegativity and oxygen kinetics during E-H transition in inductively coupled radio frequency plasmas . — •Thomas Wegner[1] and Jürgen Meichsner[2] — [1]Max-Planck-Institute for Plasma Physics, Greifswald, Germany — [2]Institute of Physics, University of Greifswald, Greifswald Germany

The electronegativity and oxygen kinetics in inductively coupled plasma at 13.56 MHz was evaluated during the E-H transition by comprehensive plasma diagnostics to determine experimentally the particle density for electrons, negative atomic oxygen ions, metastable and ground state molecular oxygen as well as the effective electron temperature and gas temperature. Furthermore, the negative atomic oxygen ion density was calculated by their balance equation taking into account the experimentally determined densities and temperatures as well as the rate coefficients from literature. The calculated negative ion density is compared with the measured negative ion density by laser photodetachment experiment and by the electron density peak in the early afterglow due to collisional detachment. The three different methods provide adequate agreement in the negative ion density and describe the continuous decrease of the electronegativity over two orders of magnitude from the E-mode to the H-mode. Additionally, the dominant elementary processes are identified for negative ion formation and recombination in the E-mode and H-mode, respectively.
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Characterisation of Sub-microsecond Pulsed Discharges in Water — •Raphael Rataj, Jana Kredl, Camelia Miron, Tilo Schulz, Jürgen F. Kolb, and Ronny Brandenburg — Leibniz-Institut für Plasmaforschung und Technologie e.V., Felix-Hausdorff-Str. 2, 17489 Greifswald

Corona-like plasma discharges in water that are instigated with nanosecond high voltage pulses are of great interest for water treatment and novel approaches in green chemistry. Accordingly, much effort has been spent to characterize this type of discharge depending on operating parameters. Physical processes of electrical breakdown and discharge development will be studied in a point-to-plane geometry for the application of defined 100 ns high voltage pulses. Systematic investigations of a single pulse event will include electrical diagnostics, fast imaging by iCCD-cameras and spectroscopy. First results, such as in particular on electrical characteristics and the branching ratios of streamers, will be presented and discussed.

P 23.13 Mi 16:30 HS Foyer

Characterization of the high density helicon plasma cell PROMETHEUS-A for the Advanced Wakefield Experiment — •Birger Buttenschön, Nils Fahrenkamp, and Olaf Grulke — Max Planck Institute for Plasma Physics, 17491 Greifswald, Ger-

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The Advanced Wakefield Experiment (AWAKE), the world's first proton-beam driven plasma wakefield accelerator test facility, is currently being set up and commissioned at CERN in its first stage. In order to reach significant output beam energies, an accelerating plasma section that is scalable in length to tens or hundreds of meters is required. We present a prototype plasma cell based on a high power helicon discharge ($P_{\mathrm{rf}} \leq 100$ MW/m^3) with an axially distributed antenna system. In this prototype, accelerator-relevant plasma densities of $n_{\mathrm{e}} \leq 6 \cdot 10^{20}$ m^{-3} are now routinely produced for short periods of time. The plasma is characterized by means of laser interferometry with respect to temporal density evolution, its radial distribution and the scaling with external control parameters such as ambient magnetic field, neutral gas inventory and specifics of the helicon wave coupling.

P 23.14 Mi 16:30 HS Foyer

A Computationally Assisted Spectroscopic Technique to measure secondary electron emission coefficients in technological RF plasmas — •Birk Berger[1,2], Manaswi Daksha[1], Edmund Schüngel[1], Mark Koepke[1], Julian Schulze[1,2], Ihor Korolov[3], Aranka Derzsi[3], and Zoltán Donkó[3] — [1]Department of Physics, West Virginia University, Morgantown, USA — [2]Institute for Electrical Engineering, Ruhr-University Bochum, Germany — [3]Wigner Research Centre for Physics, Hungarian Academy of Sciences, Hungary

A Computationally Assisted Spectroscopic Technique to measure secondary electron emission coefficients (y-CAST) in capacitively coupled radio-frequency plasmas is proposed. This non-intrusive, sensitive diagnostic is based on a combination of Phase Resolved Optical Emission Spectroscopy and particle-based kinetic simulations. In such plasmas the spatio-temporally resolved electron-impact excitation rate features two distinct maxima adjacent to each electrode at different times within each RF period. While one maximum is the consequence of the energy gain of the electrons due to sheath expansion, the second maximum is produced by y-electrons accelerated towards the plasma bulk by the sheath electric field at the time of maximum voltage drop across the adjacent sheath. Due to the different excitation mechanisms the ratio of the intensities of these maxima is very sensitive to y, which allows for its determination via comparing the experimentally measured excitation profiles with corresponding simulation data obtained with various y-coefficients. This diagnostic is tested here in a geometrically symmetric reactor, for stainless steel electrodes and argon gas.

P 23.15 Mi 16:30 HS Foyer

Phase resolved laser absorption spectroscopy on a low pressure dielectric barrier discharge jet — •Roman Bergert and Slobodan Mitic — I. Physikalisches Institut, Justust-Liebig Universität Gießen

Dielectric barrier discharge (DBD) jets at low pressures ($\approx$ 100 Pa) were investigated by laser absorption targeting the 1_{s4} argon resonant state at 842.46 nm and fluorescence spectroscopy. The accuracy of the measurements was improved by synchronization of the laser scan with the voltage dynamics providing the possibility for phase resolved reconstruction of the measured absorption profiles.

Preliminary fits with a Gaussian profile resulted in pure description of measured profiles; wings indicating additional broadening components. The latter is considered to be caused by charge particles (Stark broadening) while pressure broadening at the applied pressures should not be detectable.

The laser absorption was measured across the jet, between electrodes, providing the phase resolved local information on the state density, gas temperature and electron density. Laser absorption in axial direction was also performed confirming strong phase dependent gas thermodynamics based on detection of Doppler shift induced florescence imaging of the plasma jet. The observed DBD jets had very strong phase dependent development with high densities and relatively low gas temperature making it a quite efficient and robust plasma source.

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Planar Multipole Resonance Probe: Comparison of a Functional Analytic Approach and Full 3D Electromagnetic Field Simulations — •Michael Friedrichs[1], Christian Schulz[2], Ilona Rolfes[2], Ralf Peter Brinkmann[3], and Jens Oberrath[1] — [1]PPI, Leuphana University Lüneburg, Germany — [2]HFS, Ruhr-University Bochum, Germany — [3]TET, Ruhr-University Bochum, Germany

Measuring plasma parameters, e.g. electron density and electron temperature, is an important procedure to verify the stability and behavior of a plasma process. For this purpose, the multipole resonance probe (MRP) represents a promising design. However, the influence of the probe on the plasma through its physical presence makes it unattractive for most processes in industrial applications.

A solution, suitable for industrial applications, is the planar version of the MRP (pMRP). It combines the design and benefits of the spherical MRP and can be mounted into the chamber wall.

To analyze the resonance behavior of the pMRP the cold plasma model is coupled to the Poisson equation and an analytical expression for the admittance of the probe-plasma system can be derived by means of functional analytic methods. It is adjusted to the design of the pMRP in cylindrical geometry and the corresponding spectra are compared to full 3D electromagnetic field simulations. Based on the Finite Integration Technique, the commercial software CST Microwave Studio is utilized for these simulations. The resulting complex reflection coefficient is evaluated, obtained by the frequency domain solver in conjunction with a tetrahedral mesh and the Drude model.