P 2: Plasma Diagnostics I

Time: Monday 11:00–13:10 Location: b305

Invited Talk P 2.1 Mon 11:00 b305

Mid-infrared cavity enhanced absorption spectroscopy of gas and surface species — •Jean-Pierre van Helden, Norbert Lang, Andy Nave, and Jürgen Röpcke — Leibniz Institute for Plasma Science and Technology (INP Greifswald), Greifswald

Understanding how plasmas interact with solid and liquid surfaces is of central importance in many fields such as microelectronics, materials and surface processing and in environmental and biomedical technologies. Improving process efficiency requires a comprehensive understanding of the kinetics of the transient intermediates involved at the plasma-substrate interface. The experimental approaches currently available provide an incomplete picture of plasma-surface interactions due to relatively low sensitivity. A further increase in sensitivity to detection limits of ppm down to ppt levels can be achieved by combining quantum and interband cascade lasers (QCLs and ICLs) with cavity-enhanced techniques based on optical cavities. The surface species can be detected by combining EC-QCLs with evanescent-wave attenuated-total-reflection (EW-ATR) spectroscopy. Cavity enhanced absorption spectroscopy can also be combined with ATR measurements. It was recognized early on in the development of cavity enhanced spectroscopies that if the internal reflection element in which the evanescent-wave is generated in ATR is included in the cavity it would greatly enhance ATR sensitivity. Here, the latest results in the development and applications to plasmas of mid-infrared cavity enhanced absorption spectroscopy of gas and surface species will be presented.

Fachvortrag P 2.2 Mon 11:30 b305

Charge-exchange from fast atoms in X-ray spectra — •Tobias Schlummer[1], Oleksandr Marchuk[1], Dave Schultz[2], Günter Bertschinger[1], Wolfgang Biel[1], and Detlev Reiter[1] — [1]Institut für Energie- und Klimaforschung, Plasmaphysik, Forschungszentrum Jülich GmbH, 52425 Jülich — [2]Department of Physics, University of North Texas, Denton, TX 76203, USA

Charge exchange recombination (CX) is an important atomic process in astrophysical and laboratory plasmas. It describes the capture of a bound electron from an atom A by an ion X^z: $[X^z + A^q \rightarrow X^{z-1} + A^{q+1}]$. The newly formed ion X^{z-1} is preferentially in a highly exited state causing subsequent line emission. This line emission strongly depends on the final-state-resolved CX cross sections. However, the available theoretical data sets diverge significantly restricting the accuracy of spectroscopic measurements. Recently, a first experimental testing of the high energy final-state-resolved CX cross sections was performed at the TEXTOR tokamak using X-ray spectroscopy. The Rydberg series and the K_α spectrum of He-like argon were measured in the beam path of a 50 keV neutral hydrogen injector. The observed line enhancement caused by the interaction of H-like argon ions with the fast neutrals shows good agreement with the theoretical expectation based on one set of CX cross sections. The CX contributions from H($n = 1$) and H($n \geq 1$) atoms are clearly separable in the spectra. It is shown that the number of beam excited states is limited to principal quantum numbers $n \approx 10$ confirming recent models for fast atoms in fusion plasmas using parabolic quantum states.

P 2.3 Mon 11:55 b305

Dual frequency multichannel boxcar THz time domain spectroscopy measurements for the determination of the temporal evolution of the plasma density in pulsed low-pressure plasmas — •Steffen Marius Meier, Tsanko Vaskov Tsankov, Dirk Luggenhölscher, and Uwe Czarnetzki — Institut für Experimentalphysik V, Ruhr-Universität Bochum, 44780 Germany

THz time domain spectroscopy (THz TDS) is a non-invasive diagnostic method that allows the determination of the electron density and even the collision frequency. In contrast to microwave interferometry, THz TDS combines the advantages of a pico-second radiation pulse with a broad spectral width in the THz range ensuring better resistance to noise and vibrations. For the purpose of time-resolved measurements a standard THz TDS system was upgraded to improve the signal to noise ratio and the detection threshold. To achieve this, the detection method had to be changed. The lock-in frequency was increased from 7.6 kHz to 38 MHz to allow integration over more pulses within a shorter time. Additionally, a high performance lock-in amplifier is used that allows dual frequency multichannel boxcar measurements. Now measurements with less than 200 ps resolution are possible. The detection threshold was lowered to about $1 \cdot 10^{11}$ cm^{-3} or more precisely $1 \cdot 10^{12}$ cm^{-2} line integrated.

The current status of the project as well as results from temporally resolved plasma density measurements in inductively coupled magnetic multi-cusp argon and neon low-pressure discharges are presented.

P 2.4 Mon 12:10 b305

Laser four-wave mixing electric field strength measurements of filamentary DBDs — •Patrick Böhm[1], Manfred Kettlitz[2], Ronny Brandenburg[2], Hans Höft[2], and Uwe Czarnetzki[1] — [1]Institute for Plasma and Atomic Physics, Ruhr-University Bochum, 44801 Bochum, Deutschland — [2]INP Greifswald, 17489 Greifswald, Germany

In this contribution a four wave mixing technique based on Coherent anti-Stokes Raman spectroscopy (CARS) is used to measure electric field strengths in filamentary DBD discharges. The discharges are operated with a pulsed DC voltage in nitrogen at atmospheric pressure. For the investigation of the electric field an admixture of 5% - 10% of hydrogen is added as a tracer gas to ensure measurable signal intensities. The obtained measurement threshold is below the ignition field strength. Calibrating the system results in the determination of the absolute electric field strength in the measurements and also gives the breakdown voltage of the setup simultaneously. Current and voltage measurements ensure that the technique does not influence the discharges, i.e. that it is non-invasive. Alteration of the electric field has been observed during the internal polarity reversal and the breakdown process. In this case the major advantage over emission based methods is that this technique can be used independently from emission, e.g. in the pre-phase and in between two consecutive, opposite discharge pulses where no emission occurs at all. Therefore the CARS-based method could contribute to a better understanding of surface charge build-up, compensation and relaxation phenomena.

P 2.5 Mon 12:25 b305

Design, Setup, and Calibration of a Two-Wavelength Imaging Interferometer for the Diagnostics of Switching Arcs — •Jan Carstensen, Patrick Stoller, Sandor Simon, Philipp Jabs, and René Salzmann — ABB Corporate Research, Baden-Daettwil, 5405, Switzerland

Interferometric, schlieren and shadowgraphy methods, which are sensitive to the refractive index of a gas, are well established flow visualization techniques and have been applied to the diagnostics of electric arcs in high-voltage switching equipment, among many other things. In the vicinity of the arc the interpretation of the results is not straightforward, because the Gladstone-Dale relation, which connects the gas density with the measured refractive index, is not valid for temperatures above 2000 K, and ionization and dissociation processes have to be taken into account. This is a problem in particular during the zero crossing of the current –the moment when the current can be interrupted– since the hot arcing channel is in a non-equilibrium state, greatly complicating the modeling of the gas composition. One promising approach to tackle this problem is to introduce a second wavelength that allows a direct measurement of the electron density (see Refs. [1,2]). In this contribution we will present our design of a compact and flexible two-color imaging interferometer. The accuracy of the systems is proven using appropriate reference objects and first measurements of an electric arc embedded in a transonic gas flow are presented.

[1] K. Muraoka, et al., Jap. J. Appl. Phys., 19, L293 (1980)
[2] Y. Inada, et al., J. Phys. D, 47, 175201 (2014)

P 2.6 Mon 12:40 b305

investigation of gas parameters at high electrical field strength and under atmospheric gas pressure — •xingming fan, lothar naumann, mathias siebold, marcus kaspar, jörn dreyer, burkhard kämpfer, roland kotte, alejandro laso garcía, markus löser, ulrich schramm, and daniel stach — Helmhotz-Zentrum Dresden-Rossendorf

The laser test facility of the Helmholtz-Zentrum Dresden-Rossendorf for more precise measurements of different gas parameters in microgap geometries with high electrical field up to 100kV/cm and at normal pressure will be presented. The light of 257nm is focused into the gas to initialize primary electrons by multiphoton ionization. The diameter of the focus is less than 20μm and the length is lesser than 500*m. The Townsend coefficient and electron drift velocity are presented for several gas mixtures. Simulations with the Garfield++ framework were performed for comparable geometries, gas mixtures and electrical fields. Experimental and simulation results will be discussed.

P 2.7 Mon 12:55 b305

Messung und Simulation des Kraftvektors auf Festkörperoberflächen beim Sputtern im Ionenstrahl — •Alexander Spethmann, Thomas Trottenberg und Holger Kersten — Institut für Experimentelle und Angewandte Physik der CAU zu Kiel

Der Sputter-Effekt wird üblicherweise durch die Sputterausbeute (Sputtering Yield), d.h. zerstäubte Teilchen pro einfallendes Teilchen, quantifiziert. Die experimentelle Bestimmung der Sputterausbeute kann üblicherweise durch Messung der Massenänderung des Sputtertargets, Änderung seiner Schichtdicke, Detektion der gesputterten Teilchen mit spektroskopischen Methoden oder durch dessen Einfang mittels Kollektorflächen erfolgen.

In diesem Beitrag hingegen werden Messungen der Kraft auf ein ebenes Messtarget mit einer neuartigen interferometrischen Sonde im Ionenstrahl einer Breitstrahlquelle vorgestellt. Teilchen aus dem Strahl, gesputterte Targetteilchen und reflektierte Teilchen führen zu einem auf das Messtarget wirkenden Kraftvektor. Das Messtarget ist am freien Ende eines einseitig eingespannten Biegebalkens fixiert, wobei durch Messung seiner Verbiegung mit zwei zueinander orthogonal angeordneten interferometrischen Sensoren der Kraftvektor zweidimensional und durch Drehung der Sonde im Strahl auch einfallswinkelabhängig bestimmt werden kann.

Die ermittelten Kraftvektoren werden mit denen durch einer auf SRIM basierten Simulation generierten verglichen. SRIM ist ein populärer Code zur Berechnung von atomaren Zweierstoßkaskaden.