P 13: Low Pressure Plasmas - Poster

Time: Tuesday 16:15–18:15 Location: Redoutensaal

P 13.1 Tue 16:15 Redoutensaal

Electron Impact Excitation of Xenon — •Dirk Luggenhölscher[1], Uwe Czarnetzki[1], Oleg Zatsarinny[2], and Klaus Bartschat[2] — [1]Ruhr-Universität Bochum — [2]Drake University, Iowa, USA

A novel experimental technique is applied to measure cross sections for electron-impact excitation of the $5p^5 6p$ state of xenon from its $5p^6$ ground state. This is a complex collision system, for which benchmarking of theory against experiment is needed. The experiment is performed using ultrashort current pulses released from an electrode by femtosecond laser pulses with 80 MHz repetition rate. In order to minimize space charge effects, only about 10^4 electrons are generated in each pulse. Electrons are accelerated by a homogeneous electric field to energies of typically 250 eV. The fluorescence light (transition from $5p^5 6p$ to $5p^5 6s$) generated after collisions with Xe atoms at low pressure (Pa range) is observed perpendicular to the electron beam direction and provides a direct image of the energy-dependent excitation cross section. The calculations were carried out with a fully relativistic and parallelized version of the B-spline R-matrix code [1], using a 75-state close-coupling model [2] with the target structure obtained earlier [3]. The work of OZ and KB is supported by the US NSF under PHY-1403245, PHY-1520970, and XSEDE-090031.

[1] O. Zatsarinny, Comp. Phys. Commun. **174** (2006) 273
[2] O. Zatsarinny and K. Bartschat, J.Phys.B: At. Mol. Opt. Phys.**43** (2010) 074031
[3] O. Zatsarinny and K. Bartschat, Phys. Scr. T. **134** (2009) 014020

P 13.2 Tue 16:15 Redoutensaal

Spectroscopic investigations of the silyl radical using a quantum cascade laser — Andy S. C. Nave[1], Andrei V. Pipa[1], Paul B. Davies[2], Jürgen Röpcke[1], and •Jean-Pierre H. van Helden[1] — [1]Leibniz Institute for Plasma Science and Technology, Greifswald, Germany — [2]Department of Chemistry, University of Cambridge, Cambridge, United Kingdom

Silane-based plasma enhanced chemical vapour deposition is an established process for producing hydrogenated amorphous silicon (a-Si:H) films for the solar cell industry. The most abundant product of the fragmentation of SiH4 is the silyl radical, SiH_3, next to other short-lived silicon containing species, such as SiH_2, SiH, Si and related ionic species. The development of increasingly more sensitive spectroscopic techniques to determine the concentration of these short-lived species is essential to enhance our knowledge of the complex chemical processes involved. We report on the measurement of a line strength in the ν_3 fundamental band of the silyl radical using a quantum cascade laser. Rotationally resolved lines of SiH_3 between 2085 and 2175 cm^{-1} were measured in RF pulsed plasmas containing 10% SiH4 in He and in H2. The line strength of one of these lines, free from interfering transitions, was measured by analysing the radical concentration profile when the discharge was extinguished. The absolute line strength of the silyl radical absorption feature at 2119.947 cm^{-1} from the $^pP_6(9)$ transition was determined to be $4.82 \pm 2 \times 10^{-21}$ cm^{-1} $molecule^{-1}$ cm^2.

P 13.3 Tue 16:15 Redoutensaal

Diagnostics on a hollow cathode glow discharge by means of a retarding field analyser and a calorimetric probe — •Lisa Anna-Maria Bauer, Fabian Haase, Sven Gauter, and Holger Kersten — Institute of Experimental and Applied Physics (IEAP), Kiel University, Germany

In this work a cylindrical DC hollow cathode glow discharge is combined with an axially directed magnetic field in order to increase the plasma density. By rising the magnetic field strength the efficiency of the so called hollow cathode effect can be enhanced. A retarding field analyser and a passive thermal probe are used to characterise positive ions, which impact the negative biased cathode. These ions are, for instance, responsible for sputter processes, especially, for deposition rate and homogeneity during thin film deposition. Therefore, it is important to determine their energy distribution and their energy input to the cathode surface. Varying parameters in this work are the cathode material, gas pressure, magnetic field strength, discharge mode (DC and HiPIMS) and the distance between the probes and the cathode surface.

P 13.4 Tue 16:15 Redoutensaal

Experimental studies of momentum transfer during sputtering with interferometric force probes — •Mathis Klette, Thomas Trottenberg, and Holger Kersten — Institute of Experimental and Applied Physics (IEAP), Kiel University, Germany

In this work an ion beam is focused on a plane sputter target at different angles of incidence. The resulting sputter plume is characterized using Interferometric force probes [*]. In contrast to conventional diagnostics, a force probe does not rely on charged particles, but takes also neutrals into account and supports a more comprehensive picture of the sputtering process. The force vector resulting from implanted and reflected beam particles and sputtered target atoms is measured using a double axis force probe. A second force probe is used to circle around the target scanning through the resulting plume of sputtered target atoms and beam particles. The determined forces are then compared with simulation data using SRIM [**]. The experimental setup allows a variation of angle of incidence, target material, ion energy, gas type and gas pressure.

[*] Spethmann, A., Trottenberg, T., Kerst en, H., Phys. Plasmas **24**(2017), 093501.
[**] J. Biersack and L. Haggmark, Nucl. Instrum. Methods **174**, 257 (1980).

P 13.5 Tue 16:15 Redoutensaal

Quantum kinetic theory of ion-induced secondary electron emission from surfaces — Mathias Pamperin, •Franz Xaver Bronold, and Holger Fehske — Institut für Physik, Ernst-Moritz-Arndt-Universität Greifswald, 17489 Greifswald, Germany

Secondary electron emission due to atomic species hitting the wall of a gas discharge is an important surface collision process strongly affecting the charge balance of the discharge. At impact energies typical for low-temperature plasmas electrons are ejected due to the transfer of the internal potential energy stored in the projectile's electronic structure. To describe this process quantitatively we set up a general quantum-kinetic approach and applied it to an He^+ ion hitting a metallic wall. Based on a semi-empirical multi-channel Anderson-Newns model, projection operator techniques, and the non-crossing approximation for the self-energies we derived rate equations for the occurrence probabilities of the projectile's electronic configurations which may become operational in the course of the collision process. From it we also deduce the electron emission spectrum as a function of impact energy and angle. Auger neutralization of the positive ion as well as Auger de-excitation of radicals and/or negative ions, temporarily formed by single-electron transfers, are treated on an equal footing. For grazing incidence we get rather good agreement with experimental data indicating our approach captures the essential physics involved. Having in mind the tailoring of the electron emission spectrum by a judicious choice of the wall material we present results for various metals. – Supported by DFG through CRC/Transregio TRR24.

P 13.6 Tue 16:15 Redoutensaal

Untersuchungen zur Trichterkompression von Plasmen koaxialer Beschleuniger — •Thomas Manegold, Parysatis Tavana, Christian Benzing, Marcus Iberler und Joachim Jacoby — Institut für Angewandte Physik, Goethe Universität Frankfurt am Main

In diesem Beitrag werden spektroskopische Messungen zur Trichterkompression von Plasmen, die durch koaxiale Elektrodengeometrien erzeugt und beschleunigt werden, präsentiert.

Der zugrundeliegende Aufbau verfügt über einen Energiespeicher von 27uF bei Spannungen von bis zu 10kV. Die aus den erzielten Strömen von bis zu 150kA resultierende Lorentzkraft beschleunigt das Plasma in eine aus Glas bestehende Trichtergeometrie wodurch das Plasma verdichtet wird und sich die Elektronendichte um einen Faktor von etwa 600 im Vergleich zur Messung ohne Trichter erhöht. Die durch die Kompression erreichten Elektronendichten liegen im oberen Bereich von $10^{17} cm^{-3}$, sodass sich die Verbreiterung der H_β-Linie nach dem linearen Stark-Effekt nur noch sehr eingeschränkt verwenden lässt. Als Alternative hierzu wurde die Verbreiterung einer Kupfer-Linie bei 479,40nm unter Verwendung des quadratischen Stark-Effekts zur Bestimmung der Elektronendichte verwendet. Zudem werden Messungen der emittierten VUV-Strahlung der Plasmen gezeigt.

P 13.7 Tue 16:15 Redoutensaal

Characterization of a portable measurement device for the determination of absolute VUV emission of low pressure plasmas — •Caecilia Fröhler[1], Roland Friedl[1], Stefan Briefi[1,2], and Ursel Fantz[1,2] — [1]AG Experimentelle Plasmaphysik, Universität Augsburg, 86135 Augsburg — [2]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching

Photon fluxes in the vacuum ultraviolet spectral region (VUV, wavelength below 200 nm) play a role during surface treatment processes with low pressure plasmas. Depending on the photon wavelength and the application, VUV radiation can have beneficial or undesirable effects on the surface material. For obtaining wavelength-resolved information on photon fluxes, expensive and large vacuum spectrometers are neccessary which have to be calibrated specifically at the discharge setup of use. For this reason, a small and portable measurement system based on a silicon VUV diode is being under development in which spectral resolution is achieved by using bandpass or edge filters. Its calibration is independent of the setup what makes the device transferable to any type of plasma application. An absolute calibration is performed against a calibrated VUV spectrometer in a laboratory hydrogen ICP discharge (Ø15 cm, height 10 cm; 2 MHz; 2 kW). The spectral composition is investigated simultaneously with the spectrometer and the diode system for pressure and power scans in order to demonstrate the applicability as an easy-to-use diagnostic tool for VUV fluxes.

P 13.8 Tue 16:15 Redoutensaal

Protective coating for electronic assemblies against environmental influences - a high throughput low pressure plasma process for in-line integration — Fabian Utzmann[1], •Florian Eder[1], and Bastian J. M. Etzold[2] — [1]Siemens AG Corporate Technology, 91058 Erlangen, Germany — [2]Technische Universität Darmstadt, 64287 Darmstadt, Germany

Printed circuit boards need to be protected against corrosive influences in order to guarantee functionality and safety. In this regard, current varnish based solutions do not always provide a flawless conformal coating and require extensive processing efforts. Replacing these coatings by a plasma polymer will allow improving overall protection properties while reducing processing costs. Yet, current plasma coaters are not designed for a seamless integration into existing electronic production lines. The challenge is to use standard handling and transportation systems in electronic production as substrate carriers in the plasma coater. To counter these challenges a new plasma reactor was designed from scratch around a substrate carrier. This allows a coating application onto a stack of printed circuit boards as well as a corresponding development of coatings including precursor and process parameter evaluation. The deposited coatings were characterized regarding film thickness, defect density, chemical structure elucidation by fourier transform infrared spectroscopy and protection properties in standard temperature and humidity tests.

P 13.9 Tue 16:15 Redoutensaal

Application of an AC method for measuring the EEDF in low pressure plasmas by a Langmuir probe — •Adrian Heiler[1], Roland Friedl[1], and Ursel Fantz[1,2] — [1]AG Experimentelle Plasmaphysik, Universität Augsburg, 86135 Augsburg — [2]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching

The electron energy distribution function (EEDF) in low pressure low temperature plasmas is often non-Maxwellian and therefore needs to be measured in experiment. The most straightforward approach to determining the EEDF is to measure the *I-V* characteristic of a Langmuir probe and numerically differentiate it twice (Druyvesteyn correlation). However, numerical differentiation requires data smoothing techniques and leads to inevitable numerical errors. Therefore, a Langmuir probe method first proposed in the 1930s by Sloane and MacGregor (1934 *Phil. Mag.* **18**, 193) was adopted to directly measure $\mathrm{d}^2I/\mathrm{d}V^2$. This is done by superimposing a sinusoidal AC voltage on the probe DC bias and Fourier transformation of the corresponding probe current. Besides avoiding numerical errors, the AC method provides access to a higher dynamic range of the EEDF due to better signal-to-noise ratio.

The system is implemented for a sinus frequency of 13 kHz and a variable amplitude in the range of 1 V. Moreover, it is also capable of measuring and analysing the probe *I-V* characteristic. The system is tested in an ICP discharge (planar coil, RF 2 MHz, power up to 2 kW) in the $1-10$ Pa pressure range and compared to a conventional Langmuir probe system.

P 13.10 Tue 16:15 Redoutensaal

Investigation of a low pressure microwave plasma source for high rate etching — •Steffen Riegger[1], Andreas Schulz[1], Matthias Walker[1], Günter Tovar[1], Mario Dünnbier[2], and Klaus Baumgärtner[2] — [1]Institute of Interfacial Process Engineering and Plasma Technology IGVP, University of Stuttgart, Stuttgart, Germany — [2]Muegge GmbH, Reichelsheim, Germany

Photoresists are used in the industry for lithographic processes to produce surface structures in the sub-micrometer range. After the manufacturing processes the cured photoresist must be removed. For this purpose we investigate a remote plasma source (RPS). For the etching process pure oxygen is chosen as working gas instead of halogens to prevent environmental issues. The generated oxygen radicals react with the substrate surface atoms forming gaseous molecules. To study the processes in the RPS, the plasma is spectroscopic investigated and planar etch rates as a function of different changing parameters like the microwave power were determined. High etching rates in the range of $1\frac{\mu m}{s}$ can be achieved. The spectrum of the here used oxygen plasma shows the typical atomic oxygen lines (777 nm and 844 nm). Also several ion molecule bands in the UV- range between 220 nm and 390 nm of the O_2^+- 2nd negative system and in the visible range between 500 nm and 600 nm of the O_2^+- 1st negative system are seen. The areas in the RPS where the ions are generated could be determined by a UV-transparent bandpass filter. The generation of the ions correlates with the microwave coupling into the plasma source.

P 13.11 Tue 16:15 Redoutensaal

Plasma enhanced chemical vapour deposition and plasma etch challenges for technological fabrication of silicon nitride photonic components — •Erik Lehmann[1,2], Harald Richter[1], Mirko Fraschke[1], Marco Lisker[1], Thomas Grabolla[1], Lars Zimmermann[1,3], and Andreas Mai[1,2] — [1]IHP, Im Technologiepark 25, 15236 Frankfurt (Oder) — [2]Technische Hochschule Wildau, Hochschulring 1, 15745 Wildau — [3]Technische Universität Berlin, HFT 4, Einsteinufer 25, 10587 Berlin

In the last years silicon nitride (SiN) is demonstrated as a high performance solution for photonic integrated circuits. SiN is emerging as a possible alternative silicon photonics platform with additional features and strength.

The present work is focused on the development of a manufacturing process for silicon nitride waveguides and grating couplers. Experiments have shown plasma enhanced CVD power is significant for high-quality SiN waveguides. An additional polish step was implemented to decrease the surface roughness. The following SiN plasma etch process using a CF chemistry results in waveguides characterized by a rectangular profile with minimal sidewall roughness. The hydrogen concentration in SIN is reduced by a final annealing step. Propagation loss values less than 0.5 dB/cm verify the technological manufacturing process quality.

P 13.12 Tue 16:15 Redoutensaal

Structural Characterization of VOx deposited by Plasma Ion Assisted Electron Beam Evaporation for Energy Storage Application — •Miguel Dias[1], Anna Frank[2], Stefan Hieke[2], Simon Fleischmann[3,4], Jens Harhausen[1], Rüdiger Foest[1], Volker Presser[3,4], Christina Scheu[2,5], and Angela Kruth[1] — [1]INP Greifswald, Germany — [2]MPIE Düsseldorf, Germany — [3]INM Saarbrücken, Germany — [4]Dept. of Mat. Sci. and Eng., Saarland University, Germany — [5]Materials Analytics, RWTH Aachen University, Germany

Vanadium oxide-based materials are of interest for electrochemical energy storage applications but controlled synthesis at large scale is still challenging. Electron beam evaporation assisted by plasma ions was performed to synthesize VOx thin layers on Si and CNT. Plasma properties such as ion velocity distributions were obtained for different O2 content of the working gas, substrate temperature, applied discharge voltage and current. Structural analysis of thin film properties was carried out by means of XRD and Raman spectroscopy as well as HR-TEM in combination with EELS. First correlation between plasma parameters and resulting structural properties were established indicating a strong dependence of the crystallinity on the ion energy and chamber temperature. VOx was deposited directly on free-standing CNT to obtain hybrid electrode materials that combine redox activity with high electrical conductivity. First electrochemical characterizations show promising activities and potential for their usage as electrodes for their use as electrodes in lithium-ion batteries.

P 13.13 Tue 16:15 Redoutensaal

An optically trapped microparticle as a probe — •Viktor Schneider and Holger Kersten — Institute of Experimental and Applied Physics (IEAP), Kiel University

In contrast to common plasma diagnostic tools, e.g. Langmuir probes, calorimetric probes, mass spectrometers etc., the μPLASMA (microParticles in a Discharge with Laser Assisted Manipulation) experiment uses optically trapped microparticles (SiO_2) as nonivasive probes. The displacement of the particle in the trap is used to measure a force while it is moving relatively to the plasma, either deeper into the sheath or towards the plasma bulk. In addition, information about the neutral gas damping of the particles is presented. Systematic measurements of the residual charges on the particle after turning off the plasma are measured, depending on the position of the particle in the plasma. Furthermore, charging of the sphere by UV radiation is investigated and discussed.

P 13.14 Tue 16:15 Redoutensaal

MEMS sensor for the determination of ion energy and ion angle distribution functions in low pressure plasmas — •Marcel Melzer[1], Kerstin Rössel[2], Chris Stöckel[1,3], Sven Zimmermann[1], and Thomas Mussenbrock[2] — [1]Technische Universität Chemnitz, Zentrum für Mikrotechnologien, 09126 Chemnitz — [2]Brandenburgische Technische Universität Cottbus-Senftenberg, Theoretische Elektrotechnik, 03046 Cottbus — [3]Fraunhofer-Institut für Elektronische Nanosysteme, Abteilung Multi Device Integration, 09126 Chemnitz

Low pressure plasmas are one of the most important tools for the manufacturing of integrated circuits and enable, for example, the dry etching of transistor structures with feature sizes below 14 nm. For such sophisticated plasma processes both the ion energy distribution function (IEDF) and the ion angular distribution function (IADF) of the applied plasmas are crucial parameters for the creation of the desired structures. By combining a silicon-manufactured retarding field analyzer and a microelectromechanical system (MEMS) for angular selection of the ions to be detected, the IEDF and the IADF are to be measured simultaneously by a novel sensor element. In this work, simulation results of the three-dimensional ion dynamics within the retarding field analyzer element and IEDF measurement results are presented. Furthermore, the finite element modeling and simulation of the MEMS angular selector provides an outlook on the sensor module for the measurement of ion angular distribution functions.

P 13.15 Tue 16:15 Redoutensaal

Production of a high-density plasma channel for laser acceleration — •Daiyu Hayashi[1] und Tatsuo Shoji[2] — [1]Philips Research Eindhoven, The Netherlands — [2]Nagoya University, Japan

In the framework of IZEST laser acceleration program, we develop a long (50 cm) and narrow (a few mm) plasma channel with a hollow electron density profile by helicon-wave discharges. First, we generate high-density plasmas by Helicon wave discharges in a narrow glass tube, where a hollow neutral gas profile is formed due to neutral depletion. Thereafter high-intense laser radiation will be introduced into the plasma channel to ionize fully the neutral gas of the hollow profile. In this talk, we report on the generation of high-density plasmas of 10^{14} cm^{-3} in a narrow glass tube of 4 mm in diameter and 50 cm by the m=1 mode of Helicon wave excitation under a magnetif field of 1 kG. The applied rf power is up to 3kW at the frequency of 13.56MHz. The electron density measured by a Langmuir probe was of the order of 10^{14} cm^{-3}. The formation of a hollow neutral density profile was observed by an optical emission spectroscopy.

P 13.16 Tue 16:15 Redoutensaal

Phase-resolved plasma diagnostics of a low-pressure dielectric barrier discharge — •Daniela Coenen and Slobodan Mitic — I. physikalisches Institut, Justus-Liebig-Universität Gießen, Germany

A dielectric barrier discharge (DBD) in jet configuration was investigated in a pressure range from 10 Pa to 100 Pa in argon atmosphere. A glass tube was used as dielectric and a sinusoidal voltage with a frequency of 30 kHz was applied to ignite the discharge. Various phase-resolved diagnostics were combined to get deeper insight in the temporal and spatial dynamics of DBD at low pressures. Phase-resolved emission was recorded by an ICCD camera with an exposure time of 10 ns to get information about ignition dynamics of the DBD. Density and temperature of all four 1s states (in Paschen's notation) were measured using phase-resolved tunable diode laser absorption spectroscopy (TDLAS). Both followed distinct variations during one voltage cycle. The temporal dynamics of the 1s densities are in accordance with the results from the ICCD camera measurements. The changes in temperature of the 1s states indicate a change in production mechanism of 1s levels within one voltage cycle. In general measured temperatures are low and densities comparatively high.

P 13.17 Tue 16:15 Redoutensaal

Ellipsometric Analysis of Nanostructures in Thin SiO_2-Films — •Rahel Buschhaus, Carles Corbella, and Achim von Keudell — Experimentalphysik II, Ruhr-Universität Bochum

Nanostructure of thin films plays an important role for their performance in barrier coating applications. Ellipsometric characterisation of surfaces constitutes a non-invasive analysis of the effect of plasma surface treatment. Plastic substrates such as polypropylene (PP) are of special interest for the packaging industry. PP is deposited by spin coating on silicon wafers. Silicon dioxide layers are deposited by means of pulsed microwave plasma on thin PP layers using a gas admixture of hexamethyldisiloxane (HMDSO) and oxygen. Afterwards, these layers are ion- and plasma etched in a particle beam experiment or an inductively coupled plasma (ICP) reactor, respectively. Optical properties of the barrier films are analysed during etching by spectroscopic ellipsometry to study film in-depth uniformity.

Ellipsometric porosimetry will be carried out with a modified spectroscopic ellipsometer at atmospheric pressure. The adsorption of solvents causes the change of refractive index, thereby gaining information about the pore size and pore distribution with the selection of the appropriate ellipsometric model.

The influence of the SiO_2 deposition parameters on the porosity will be analysed.