P 19: Low Pressure Plasmas and their Applications II

Time: Thursday 11:00–12:30 Location: ZHG006

Invited Talk P 19.1 Thu 11:00 ZHG006

A plasma process model for high power impulse magnetron sputtering discharges — •Martin Rudolph[1], Daniel Lundin[2], and Jon Tomas Gudmundsson[3,4] — [1]Leibniz Institute of Surface Engineering (IOM), Leipzig, Germany — [2]Plasma and Coatings Physics Divsion, Linköping University, Linköping, Sweden — [3]Science Institute, University of Iceland, Reykjavik, Iceland — [4]Division of Space and Plasma Physics, KTH Royal Institute of Technology, Stockholm, Sweden

High-power impulse magnetron sputtering (HiPIMS) processes are widely used for thin-film deposition. They rely on pulsed high discharge currents to generate a dense plasma that promotes the ionization of sputtered atoms. The ionization region model (IRM) is a semi-empirical model of the HiPIMS process. Its advantage is its computational speed, a critical factor for a process model designed to explore the vast parameter space in HiPIMS. Using the IRM, the influence of external discharge parameters on relevant internal plasma parameters can be disentangled. In this contribution, we show how the electron density in the ionization region scales with the peak discharge current, while the electron temperature scales with the sputter yield of the target material. A fraction of the ionized sputtered atoms is drawn back to the target due to its negative voltage, resulting in their loss from the deposition process. Consequently, a higher ionization of sputtered species is inherently linked to a reduction in the deposition rate. We demonstrate how these two parameters can be optimized when developing a HiPIMS process.

P 19.2 Thu 11:30 ZHG006

Investigations of EUV-induced low density hydrogen plasma in a stand-alone high-intensity irradiation setup — •Adelind Elshani[1], Linus Nagel[1], Ismael Gisch[1], Sascha Brose[1,2], Hendrik Kersten[3], Annika Bonhoff[1], Thorsten Benter[3], and Carlo Holly[1,2] — [1]RWTH Aachen University TOS, Aachen — [2]Fraunhofer Institute for Laser Technology ILT, Aachen — [3]University of Wuppertal, Physical and Theoretical Chemistry, Wuppertal

The interaction of high-intensity EUV radiation with low-pressure hydrogen gas induces a low-density hydrogen plasma. Understanding the underlying chemical and dynamic processes is essential yet complicated due to plasma formation complexity. Influencing variables are often correlated, making it challenging to investigate relevant quantities independently in existing setups. Investigations that decouple these variables are crucial for a deeper understanding of EUV-induced plasmas. The developed stand-alone high-intensity irradiation setup (EUV-HIEX) reduces complexity and allows the investigation of fundamental dependencies with mostly unbiased parameters. High-intensity exposures are achieved with high spectral purity around 13.5 nm, high vacuum quality, and symmetrical vacuum chamber geometry. Coupling diagnostics enables detailed studies of plasma-induced chemistry and dynamics. Additionally, a modeling framework is developed to link experimental data with theoretical models. The presentation covers the key components of the EUV-HIEX setup, the modeling framework, and the first experimental results, along with an analysis of simulation results regarding electron dynamics.

P 19.3 Thu 11:45 ZHG006

Characterization of a combination sensor for the diagnostic of process plasmas — •Daniel Zuhayra[1], Caroline Adam[1], Michael Weise[2], Thomas Trottenberg[1], and Holger Kersten[1] — [1]Christian-Albrechts-Universität zu Kiel — [2]Optotransmitter-Umweltschutz-Technologie e.V.

Energy and particle fluxes significantly impact the surface properties of a substrate in contact with a plasma. Therefore, process control of these parameters by plasma diagnostic methods is of special interest for industrial applications. In this study, we characterized an in-house build, combination diagnostic comprised of a Retarding-Field-Analyzer (RFA) and a Passive-Thermal-Probe (PTP), called Retarding-Field-Thermal-Probe (RFTP), for the study of energy and particle fluxes. The PTP acts as the collector of the RFA and, thus, enables the nearly simultaneous measurement of ion energy distribution and energy influx. Thereby, it is possible to split the energy flux contributions of ions and neutrals. The functionality of the diagnostic was tested in a capacitively coupled plasma (CCP) at a frequency of 13.56 MHz, a conventional direct current magnetron (DC-magnetron), a radio frequency magnetron (RF-magnetron) and in HiPIMS at various discharge conditions. The results reveal an operational area for the RFTP at pressure < 10 Pa and moderately high discharge power, limited by the dimensions, heat capacity and grid transparency of the probe.

P 19.4 Thu 12:00 ZHG006

Characterization of a plasma source for atomic tritium — •David Frese for the KAMATE-Collaboration — Tritiumlabor Karlsruhe am Institut für Astroteilchenphysik, KIT

The Karlsruhe Tritium Neutrino (KATRIN) experiment will determine a neutrino mass with a sensitivity of <0.3 eV by electron spectroscopy of the tritium beta-decay spectrum. In order to improve the sensitivity on the neutrino mass down to inverted mass ordering range or below new technologies are necessary. One proposed improvement is to use atomic tritium instead of molecular tritium. In the beta-decay of the T-atom, the intrinsic molecular broadening of about 0.4 eV is absent in the beta-decay spectrum.

The first step in generating a source based on tritium atoms is the dissociation of T_2. Therefore, various atomic tritium dissociators need to be commissioned and characterized. To address this challenge, the joint Karlsruhe Mainz Atomic Tritium Experiment (KAMATE) group was established to investigate potential atomic tritium sources. The performance of commercial dissociators is studied initially by non-radioactive hydrogen and deuterium, before transitioning to experiments with substantial amounts of tritium.

This talk presents the dissociation concept of a plasma source and highlights its advantages and disadvantages. The plasma operation may sputter off boron nitride from the cavity walls which would be detrimental for the operation. This process will be investigated in a dedicated setup. After that, the atomic fraction of the plasma dissociator outlet is studied by mass spectrometry.

P 19.5 Thu 12:15 ZHG006

Plasma Sheath Tailoring for Advanced 3d Plasma Etching: Effects of Mask Geometry and Etching Materials — •Elia Jüngling, Gerardo Gutiérrez, Marc Böke, and Achim von Keudell — Ruhr University Bochum, Germany

Three-dimensional (3D) etching of materials by plasmas represents a significant challenge for microstructuring applications to produce advanced sensors, optics and microfluidics. Previously, we proposed the use of a local magnetic field in combination with a metallic mask to manipulate the plasma dynamics above the substrate and have achieved asymmetric etching profiles [1]. The experiments were explained regarding the $\vec{E} \times \vec{B}$ drifts during the local sheath expansion in the RF plasmas. This controls the plasma density distribution above and the transport to the surface.

This concept is further investigated for the application of glass and Si 3d etching in an Ar/CF4 plasma. In the case of glass, the effect of spatially different etching rates is significantly more pronounced than that of silicon. This is presumed to be due to the differences in the etching chemistry of silicon vs. glass. Furthermore, the effect of different mask geometries has been explored. It has been demonstrated that the mask shape influences both the redeposition of sputtered CF-containing polymers from the mask surface onto the substrate and the etching profiles.

References: [1] Jüngling et al. Plasma sheath tailoring by a magnetic field for three-dimensional plasma etching. Appl. Phys. Lett. 12 February 2024; 124 (7): 074101.