P 9: Low Pressure Plasmas III

Time: Wednesday 11:00–12:30 Location: KH 01.020

Invited Talk P 9.1 Wed 11:00 KH 01.020

Controlling spokes in magnetron sputtering discharges —
•Martin Rudolph — Leibniz Institute of Surface Engineering (IOM), Leipzig, Germany

Spokes in magnetron sputtering discharges are zones of enhanced excitation and ionization that rotate along the racetrack. Their visible properties like intensity and velocity are known to depend sensitively on discharge conditions. Very intense spokes appear under conditions of strong magnetic field and low working gas pressure. In this case, spokes stand out strongly with their high emission intensity against a relatively dim background along the racetrack. This suggests that the properties of film-forming species depositing onto a substrate is dominated by the presence of spokes. The control of spoke properties may thus be an additional means to tailor the particle flux and fine-tune thin film properties. In this contribution, we discuss how such a control can be achieved using typical process parameters. We show that spoke intensity can be tuned by adjusting the working gas pressure. Moreover, we demonstrate the deliberate excitation of spokes at a defined location by introducing a step in the magnetic field strength along the racetrack. Finally, we show that spoke velocities can be adjusted using the working gas pressure and discharge current with lower velocities observed at higher gas pressures and lower discharge currents. The controlled manipulation of spokes may in the future enable spokes engineering allowing thin film properties to be tailored through deliberate tuning of spoke characteristics.

P 9.2 Wed 11:30 KH 01.020

Metal-coated plastic spheres in dusty plasmas as active particles —
•Andre Melzer, Tobias Marder, Stefan Schütt, Horst-Holger Boltz, Thomas Ihle, Christina Knapek, Daniel Maier, and Daniel Mohr — Institute of Physics, University of Greifswald, Greifswald, Germany

The dynamical properties of metal-coated dust microspheres confined in a gaseous plasma environment have been studied. It has been observed that such particles feature properties of active particles and that the particle activity changes over time and increases with the intensity of laser illumination. The dynamics of single particles as well as of small particle clusters have been analyzed quantitatively with various statistical methods to characterize their activity. Furthermore, clusters of metal-coated microspheres are observed to undergo a phase transition from an ordered to an unordered structure under increased laser illumination intensity due to the increased active motion of the particles.

P 9.3 Wed 11:45 KH 01.020

Global Clebsch coordinates for rectangular magnetron fields
— •Ralf Peter Brinkmann, Dennis Krüger, Jens Kallähn, Kevin Köhn, Lukas Vogelhuber, Yulia Sharova, Liang Xu, and Denis Eremin — Ruhr-University Bochum

Large-scale rectangular magnetrons are the workhorses of modern high-throughput coating and other plasma-processing applications. This work introduces a tool to assist in the theoretical modeling and numerical simulation of such devices: global Clebsch coordinates [1]. Focusing on the region above the cathode, the magnetic field $\boldsymbol{B}(\boldsymbol{r})$ is shown to admit a divergence-free Clebsch formulation $\boldsymbol{B} = \nabla\Psi \times \nabla\Theta$, where $\Psi(\boldsymbol{r})$ is a magnetic flux function whose constant values define nested flux surfaces, and $\Theta(\boldsymbol{r})$ is a generalized azimuth labeling individual magnetic field lines. A third coordinate $S(\boldsymbol{r})$ measures the arc length along field lines and provides a natural parameterization. The triplet (Ψ, Θ, S) defines a system of field-aligned flux coordinates suited for describing plasma behavior in large rectangular magnetrons. The topological and geometrical principles of this construction are discussed and illustrated with a realistic rectangular magnetron field. The resulting mathematical framework provides a rigorous foundation for self-consistent modeling and simulation of plasma dynamics in field-aligned flux coordinates, with direct relevance to industrial-scale plasma processing.

P 9.4 Wed 12:00 KH 01.020

Characterization of millimeter-sized low-pressure argon plasmas in aeroglass —
Karin Hansen[1], Jonas Lumma[2], Rainer Adelung[2], and •Franko Greiner[1] — [1]Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany — [2]Department of Materials Science, Kiel University, Kiel, Germany

Electrodes and other solid boundaries are invariably separated from the plasma by a layer known as the plasma sheath. Depending on the discharge pressure, this sheath has a minimum thickness on the order of the electron Debye length. The intrinsic properties of the material and its surface structure may affect the plasma. Macroscopic gaps in the surface are only filled with plasma if their size is comparable to the sheath thickness. To study how plasma-facing walls made from aeroglass[1] influence the characteristics of a low-pressure argon discharge, we generated a plasma inside a millimeter bore in an aeroglass cylinder with a height of 8 mm and a diameter of 8 mm. Since the ratio of interface area to plasma volume increases as the bore radius decreases, any influence of the aeroglass should become observable for these small systems. Plasma diagnostics were carried out using electrostatic double probes. At discharge pressures of about 1000 Pa, we observed a high-density plasma mode that does not occur with conventional wall materials.

[1] Lena M. Saure et al., ACS Nano 2023, 17, 22, 22444*22455, DOI: 10.1021/acsnano.3c05329

P 9.5 Wed 12:15 KH 01.020

Ion energy dependence of plasma TMDC modifications —
•Luka Hansen[1,2], Markus Borchardt[1], Ulrich Schürmann[2,3], Chithra H. Sharma[1], Kai Rossnagel[1,2], Lorenz Kienle[2,3], and Jan Benedikt[1,2] — [1]Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany — [2]Kiel Nano, Surface and Interface Science KiNSIS, Kiel University, Kiel, Germany — [3]Department of Materials Science, Kiel University, Kiel, Germany

Transition metal dichalcogenides (TMDCs) are two-dimensional quantum materials that could enable future technologies such as qubits or next-generation semiconductors [1]. While their intriguing electronic and structural properties have been studied extensively, questions remain about how to effectively tune these properties.

Plasma is a powerful TMDC tuning tool; e.g., it can etch multilayer systems to monolayer sheets [2]. However, the underlying plasma-TMDC interaction is not well understood. To gain more insight into these processes, we use a low-pressure reactor with inverted geometry [3], which enables us to control the ion fluxes and energies individually. Ion mass spectrometry allows us to characterize these fluxes and detect ions originating from the TMDC *in operando* as a signature of crystal decomposition. This approach will help identify plasma conditions under which TMDCs can be modified while preserving their structural integrity.

[1] K. S. Novoselov *et al.*, 2016 *Science* **353** aac9439
[2] A. Varghese *et al.*, 2017 *Nanoscale* **9** 3818
[3] C. Schulze *et al.*, 2022 *Plasma* **5** 295-305