Seminar

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Institute for Plasma Research

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Title: Studies on Magnetic Field Effects in a Capacitive Coupled Cylindrical Radio Frequency Plasma Device

Speaker: Ms. Swati
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Date: 07th June 2024 (Friday)

Time: 03.00 PM

Venue: Seminar Hall, IPR

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Abstract

Low-temperature plasmas find enormous applications in semiconductor industries, ranging from the deposition on large-area substrates to micro-chips and producing high-power neutral particle beams to provide auxiliary heating in fusion plasmas. These plasmas are generally formed using radio-frequency discharges driven either capacitively (CCP) or inductively (ICP) in the ISM band of frequencies. The driving frequency lies between the ion and electron plasma frequency such that electrons respond instantaneously to the time-varying electric fields, whereas the positive ions respond to the time-averaged sheath electric field. Positive ions accelerate the non-neutral sheath formed adjacent to the surface and interact with the material surface, leading to atomic-scale modifications. Therefore, the control over these positive ions' bombarding flux and energy are the two essential parameters in plasma processing. Over the past decades, numerous techniques have emerged to control these parameters. One promising approach for controlling the plasma parameters involves introducing a magnetic field perpendicular to the sheath electric field. However, only few experimental investigations for this exist in the public domain. Therefore, this thesis is primarily motivated to investigate the magnetic field effect on the discharge characteristics of a cylindrical CCRF plasma device using electrostatic probe diagnostics.

The thesis investigates the application of an axisymmetric magnetic field to control the characteristics of a capacitive coupled plasma device using the configuration of electrodes consisting of a large cylindrical electrode. When a magnetic field is applied tangentially to a radio-frequency (RF) powered electrode, it confines energetic electrons to the electrode surface, resulting in a non-uniform electron temperature distribution within the plasma. It is conferred by the spatially resolved Electron Energy Distribution Function (EEDF) measurements, which show a transition from non-local to local kinetic properties of electrons on applying a transverse magnetic field. The ambipolarity condition across the magnetic field lines has been considered in developing an analytical model that holds when collisions are significant in the system. It provides the radial plasma density distribution under spatially inhomogeneous electron temperature. An electrical symmetry is achieved within the geometrically asymmetric plasma device due to the reduced electron loss to the powered cylindrical electrode on applying the transverse magnetic field. A range of magnetic fields is obtained for which the device produces high plasma density due to reduced losses and enhanced ionization. However, a sharp drop in the plasma density is observed beyond this critical magnetic field range due to the localized confinement

of ionizing electrons near the electrode sheath. In conclusion, it reveals the effect of an axisymmetric magnetic field on the global and local properties of a cylindrical CCRF device.

References:

1. Swati Dahiya, Singh, P., Das, S., Sirse, N. and Karkari, S.K., 2023. Physics Letters A, p.128745
2. Swati Dahiya, P. Singh, Y. Patil, S. Sharma, N. Sirse, and SK. Karkari, Physics of Plasmas, 30(9), p.093505.
3. Swati Dahiya, Pawandeep Singh, AK Pandey and Shantanu Karkari., RF Compensated Hairpin Resonator Probe for application in Radio Frequency Discharges. (Manuscript under preparation)