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Negative ion research in laboratory devices: Physics and Modeling

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Negative ions play crucial role in material processing in semiconductor industry, is used as a source in MeV range neutral beams required for magnetic confinement fusion experiments, plasma thrusters for space propulsion, in high power plasma switches and in pair-plasma generation, to name a few. While there are plethora of applications, basic plasma physics issues remain – for example, sheath physics in negative ion dominated plasma surface interaction, understanding issues in applying conventional diagnostics to negative ion dominated plasmas, physics understanding of such plasmas to expedite identification of novel plasma sources.

At the Institute for Plasma Research, India, a new experimental setup for studying Sheath Phenomena Involving Negative ions has been setup with focus on understanding : (1) the role of electron kinetics in negative ion production and transport across magnetic field; (2) Investigation of sheaths in the presence of negative ions; (3) Generating basic experimental data for validation of theoretical model on electronegative discharge; (4) Characterization and benchmarking of novel diagnostics; (5) To study basic phenomena in negative ion plasma due to wake introduced by external perturbation and (6) Numerical Modeling. The present topic aims to highlight some recent theoretical and experimental results on negative ion source, diagnostic and sheaths involving negative ions.

Fig.1 – experimental device and plasma source

In fig-1, experimental setup for creating negative ion plasma in oxygen is shown. Negative ion formation takes place by two step process that involve electron impact excitation by fast energetic electrons, followed by dissociative electron attachment by slow electrons. However fast electrons also give rise to destruction of negative ions hence it reduces the efficiency of negative ion production in the bulk. To address the limitation, plasma sources having spatial distribution of electron temperature inside the discharge is created by interaction of dc/radio-frequency driven sheaths with an externally applied magnetic field. Negative ions are characterized using novel probing techniques based on floating Langmuir probe and dc biased hairpin probe [1].

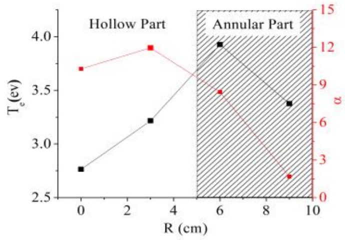

Fig.2 – Radial distribution of electron temperature and negative ion parameter $\alpha = n_{-}/n_e$ inside the source

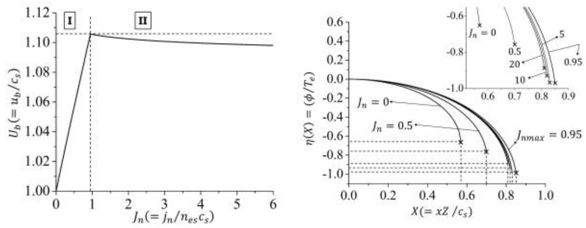

Fig.3 (a) Normalized Bohm speed U_b verses negative ion flux (b) Pre-sheath potential drop for J_n

Surface production can enhance the efficiency of negative ion production by attachment of conduction band electron of the substrate to the incoming flux of positive ions or neutrals through quantum tunneling (Augur process). This method is used in large negative ion sources by coating the plasma facing electrodes with low work function element such as cesium/barium for enhancing negative ion production. The negative ions produced at the surface are energetically accelerated towards the bulk plasma. A one dimensional sheath model of a planar negative ion emitting electrode has been developed to study the effect of negative ion emission on the sheath/ pre-sheath potential drop inside plasma [2]. The analytical result suggests that the Bohm speed of positive ions at the sheath boundary increases on account of negative ion emission flux emitting from the electrode surface, associated with a corresponding increase in potential drop across the entire pre-sheath. The analytical result is found to be in agreement with previous simulation results.

References

1. Inferring plasma parameters from sheath characteristics of a DC biased hairpin probe, A. K Pandey, J. K. Joshi, S. K. Karkari, Plasma Sources Science and Technology, 29, 015009, 0 (2019)
2. Positive ion speed at the sheath boundary of a negative ion emitting electrode, A. K. Pandey and S. K. Karkari, Contribution to Plasma Physics, 1-14 (2020)