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Study of plasma transport across magnetic filter in low temperature plasmas using 2D-3v PIC-MCC kinetic model

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Several low-temperature plasma sources such as magnetron discharges, negative ion sources, Hall thrusters, electron cyclotron resonance plasma source, and end-hall sources operate using low magnetic filter fields at low pressures. Magnetic fields used in such sources are low enough (< 7 mT) that only magnetize electrons and ions remain un-magnetized or weakly magnetized. Magnetic filter fields in such devices cool down electrons to avoid high energy electron collisions, however the presence of drifts and instabilities in the magnetic filter region leads to complex plasma transport. Several experimental and simulation works have been carried out to understand anomalous plasma transport in such low-temperature devices [1][2], however a complete clarity on this issue still remains to be achieved.

We have developed an in-house parallel 2D-3V Particle-in-Cell Monte-Carlo Collision (PIC MCC) kinetic model for a detailed understanding of the plasma transport across the magnetic field in the context of negative ion sources [3][4]. ROBIN is an RF-Oriented Beam source in India installed in IPR, India [5]. In such a negative ion source magnetic field suppress the hot electrons and reduce negative ion destruction by dissociative attachment. For efficient negative ion beam generation, the source needs uniform low energy electron density at the extraction region [3]. However, complex plasma transport and instabilities near the magnetic filter region generates non-uniformity in the extraction region.

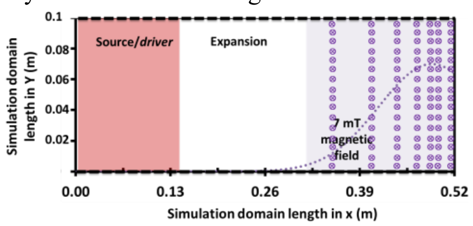

Figure 1. Simulation domain used in 2D-3V PIC-MCC simulation.

In the simulation, we have considered a simple geometry with periodic boundary condition and hydrogen chemistry. The domain is divided into three parts: source, expansion chamber, and the magnetic filter field region as shown in Fig. 1. Plasma generated in the source region using RF heating expands into the expansion chamber. A magnetic filter is placed just after expansion and before the extraction region. 2D-snapshots obtained from our simulations, as shown in Fig. 2, helps us in characterizing the plasma. Plasma density shows stripe structure in the magnetic filter region as shown in Fig. 2a. Spatio-temporal evolution of plasma density and potential in the center of the domain along the x-axis is shown in Fig. 3. PIC simulation helps in quantifying the plasma transport across the magnetic filter as well as the actual input power coupled to the plasma. EDF (energy distribution function) obtained from our simulations shows, a Maxwellian distribution for EEDF in the magnetic filter region. We have also investigated the IEDF (ion EDF), different collisional processes, and a FFT analysis to understand instabilities. Several case studies have been performed for a detailed understanding of plasma transport under different magnetic field configurations, which will help in planning future experiments [3]. We will present the detailed results from our exhaustive simulation studies and comparison with experimental results.

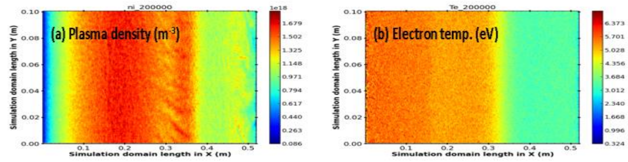

Figure 2. 2D snap-shots of plasma density (m^{-3}) and electron temperature (eV) using 2D-3V PIC-MCC simulation.

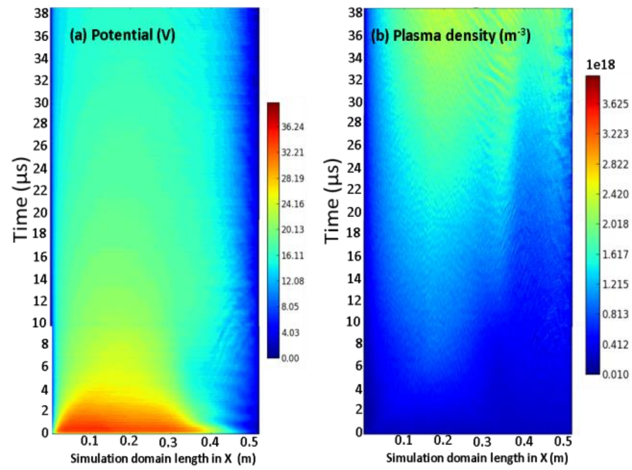

Figure 3. Temporal evolution of the potential and plasma density within simulation domain along the central X-axis.

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References

[1]Hagelaar, G. J. M. et al. Plasma Physics and Controlled Fusion, 53(12), 124032 (2011).
[2]Curreli, D. et al. Plasma Sources Science and Technology, 23(6), 064001 (2014).
[3] Shah, M. et al. Fusion Engineering and Design, 151, 11402 (2020).
[4] Chaudhury, B. et al. Communications in Computer and Information Science book series, 32–53 (2018).
[5] Bansal, G. et al. Fusion Engineering and Design, 88(6–8), 778–782 (2013).