Investigation of Ionization Instability in a Linear Plasma Device

Subir Biswas[1, 2] and Dibyajyoti Bora[1, 2]
[1] Institute of Advanced Study in Science and Technology
[2] Academy of Scientific and Innovative Research
e-mail: subirb@iasst.gov.in

Hall thrusters are electric propulsion devices with cross field ($\boldsymbol{E} \times \boldsymbol{B}$) configuration, presently used for near earth applications and emerging as a technology of choice in upcoming deep space missions like trips to Mars [1]. In Hall thruster electrons are magnetized and trapped whereas the unmagnetized heavier ion species are accelerated by the electric field and extracted from the plasma producing thrust. In spite of the advancement of the Hall thruster technology, there are several limitations of its operation because of the various instabilities that arises from the various free energy sources (e.g., density, temperature and velocity gradient etc) present in it. Among the various instabilities, ionization instability also known as breathing mode oscillations, which is related to the ionization process is supposed to be one of the most prominent instability which deteriorates the performance of Hall thrusters [2]. This low frequency oscillation mode in the longitudinal direction is accompanied by a strong periodic depletion of neutrals in the ionization area. These oscillations can cause fluctuations in thrust and efficiency, which can be detrimental to the thruster's performance. Although the ionization nature of the breathing mode is generally accepted, exact mechanism remains poorly understood and is an important area of research in basic plasma physics.

Unavailability of the ports for the insertion of the diagnostics, limitation of space and simultaneous occurrence of various instabilities in Hall thruster make it difficult to study the ionization instability in it in control manner. Therefore, linear plasma device can be helpful to study the instability in a controlled environment [3, 4]. A linear plasma device producing uniform and quiescent plasma has been fabricated indigenously at IASST for studying various waves and instabilities in a precise manner [5].

High degree of quiescence was measured in the neutral pressure range of 1×10^{-4}–1×10^{-3} mbar. However, the onset of certain instabilities results in a reduced value of plasma quiescence beyond this neutral pressure range. To investigate these phenomena, time series of the floating potential and discharge current were recorded from various spatial regions with an array of Langmuir probes at different filling gas pressures. It was observed that self-excited oscillations with distinctive frequency components were present at both higher and lower filling gas pressures as shown in Figure 1 (a-f). Frequency of the oscillation was found to be depend on filling gas pressure. Interestingly, the fluctuations detected at lower filling gas pressure appear only for a narrow pressure range just before the extinction of the plasma. Dependence of these self-excited oscillations on filling gas pressure indicates an association with the ionization instability. These floating potential fluctuations showed no phase difference when observed at different axial positions simultaneously, indicating formation of a standing wave. The dominant frequency component of these self-excited oscillations was found to be varied with different filling gases. Density fluctuations were also investigated by monitoring the fluctuations in the ion saturation region. In the present study, detailed experimental results will be presented.

References

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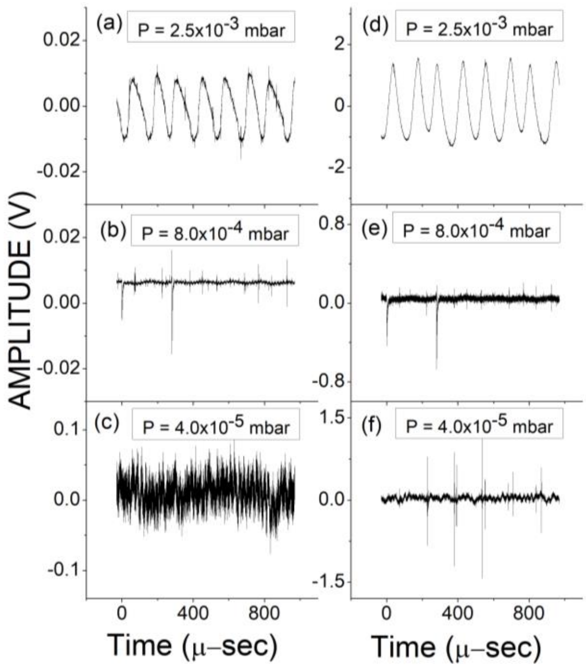

Figure 1(a-f): Time series signal of (a-c) floating potential fluctuations and (d-f) discharge current fluctuations at different filling gas pressures.