Plasma structures induced by external magnetic field

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The characteristics of 2D periodical structures in propulsion type magnetized plasma are studied in kinetic PIC MCC simulations. With increasing an obliqueness of magnetic field the ridges (maxima) of electron and ion densities form in the plasma volume in cylindrical chamber. These ridges are shifted relative each other that results in the formation of two-dimensional double-layers structure. Depending on Larmor radius and Debye length up to nineteen potential steps appear across the oblique magnetic field.

Recently some methods to control the Hall effect thruster characteristics with applying the oblique magnetic field with respect to the channel walls is widely discussed (see, [1]). Nevertheless with increasing the inclination of the magnetic field, discharge plasma properties can essentially change. For example, a several stationary, magnetized, two-dimensional weak double-layers were observed in a laboratory experiment for this type of plasma by Intrator, Menard, Hershkowitz [2].

In this paper, in kinetic simulations we consider the dc discharge plasma in the external oblique magnetic field at pressure, P=0.0001 Torr. Our purpose is to study the plasma structure modification with changing the electron temperature, magnetic field strength and obliqueness for the conditions similar to the Hall thruster ones. In our simulations, the plasma is embedded in a cylindrical chamber with the radius of 4 cm and the height H=10 cm. All walls are grounded and the cathode is biased with -90 V (grey in Fig. 1). The magnetic field B=25-100 G and magnetic field angle α_B =0-77^o. To describe the plasma in electro-magnetic field at low gas pressure we solve Boltzmann equations for the distribution functions for electrons and ions with particle-in cell Monte Carlo collision method. The Poisson equation was solved to find the electrical potential and electrical field distributions.

The periodical structure with ridges of ion and electron densities was found for larger obliqueness of magnetic field (see Fig.1). With increasing α_B the periodical plasma structure becomes clearly visible. The electron and ion ridges are shifted with respect to each other and double–layer structure appears across B-field and along the potential rise. The double-layers structure forms due to a distortion of local quasineutrality in the presence of oblique magnetic field. The electron is shifted from the ion in the direction normal to B-field and a local charge appears.

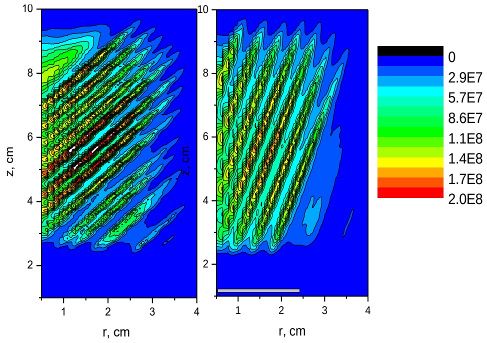

Fig. 1. Distribution of ne, cm-3 for α_B= 55^o (left) and 77 (right), B=50 G, Te=2.5 eV.

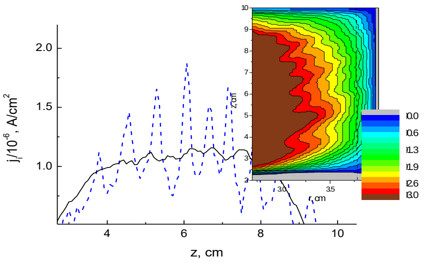

Fig.2. Ion current density over z near side wall for α_B=10^o (solid) and 65^o (dashed), potential (insert).

The ion current shown in Fig. 2 clearly indicates the periodical plasma structure. This effect can lead to an additional local erosion of wall material.

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[2] T. Intrator, J. Menard, and N. Hershkowitz, Physics of Fluids B, 5, 806 (1993).