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水素正イオンおよび表面生成負イオンを考慮した負イオン源引き出し領域近傍での電位分布

Electric Potential near the Extraction Region in Negative Ion Sources with Hydrogen Positive Ions and Surface Produced Negative Ions

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Neutral beam injection (NBI) based on a negative ion beam is a very promising method of plasma heating in future fusion reactors. In this method, hydrogen negative ions produced in negative ion sources are neutralized and injected to the plasma. As a method of producing the hydrogen negative ions, there is a surface produced method which produces the hydrogen negative ions on surface of a plasma grid (PG) in the extraction region. In study of the negative ion source, it is important to understand the plasma characteristics near the extraction region in order to extract a large amount of surface produced hydrogen negative ions. On the other hand, a recent experiment in a NIFS-R&D ion source has suggested that a "double ion plasma layer" which is a region consisting of hydrogen positive and negative ions exists near the PG surface for a case of Cs seeded negative ion source [1]. However, the characteristics in the double ion plasma layer has not been cleared.

The potential distribution near the extraction region in the surface produced negative ion sources will be studied by using the plasma-sheath equation [2]. In the analysis, the electron density in the plasma region is give as a parameter through the Debye length. The density distribution of the plasma is also obtained. From the equations of constant energy and the kinetic equations for the ion and the negative ion, the expressions of each density are derived. The electron density is given by a Maxwell-Boltzmann distribution. From the equations of the density and Poisson's equation, the plasma-sheath equation is derived. The potential distribution is obtained by solving the plasma-sheath equation numerically.

The normalized potential distribution for various values of λ_D/L is shown in Fig. 1, where λ_D is the Debye length, L is the scale length, $s=x/L$, $\Phi = (e/kT_e)(\phi - \phi_w)$, ϕ is the electric potential, ϕ_w is the wall potential, T_e is the electron temperature, $-e$ is the electron charge. The sheath width depends on the value of λ_D/L and increases as the values of λ_D/L increases. The distribution of the plasma density normalized by the electron density at s=0 for λ_D/L=0.5 is shown in Fig. 2. It is shown that the negative and positive ion densities are large near the PG surface (s=1) for a case of electron density in the plasma region is small (λ_D/L=0.5). As a result, the double ion plasma layer exists near the PG surface.

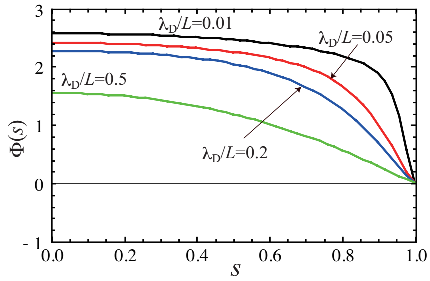

Fig.1. Profile of the potential $\Phi=(q/kT_e)(\phi-\phi_w)$ for various values of λ_D/L with β=0.4, $\tau=T_e/T_i$=2, $\tau_-=T_e/T_{i-}$=10.

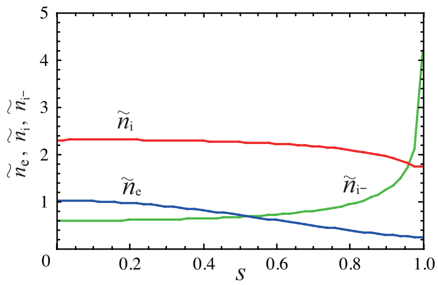

Fig.2. Profile of the plasma density normalized by $n_e(0)$ with β=0.4, $\tau=T_e/T_i$=2, $\tau_-=T_e/T_{i-}$=10, λ_D/L=0.5.

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