§8. Integrated Modeling of Negative Hydrogen (H^-/D^-) Ion Production, Extraction and Acceleration in a Large Negative Ion Source for Neutral Beam Injection System

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In N-NBI (Negative-ion-based Neutral Beam Injector) system for large fusion devices such as LHD, the optimization of 1) negative ion (H^- /D^-) production, 2) H^- /D^- extraction from the source, and 3) H^-/D^- beam acceleration towards the target are the key R&D items to obtain intense high power N-NBI beam for plasma heating.

For the optimization of the H^-/D^- extraction from the extraction hole, it is indispensable to understand the formation mechanism of the ion emissive surface (so-called plasma meniscus) and its location/shape around the extraction hole. Recently, in the NIFS-R&D ion source which is scaled a half size of the LHD ones, the following interesting experimental observation has been reported under the "surface" H^- production case with the Cs-seeding[1)] : Plasma layer consisting of H^+ and H^- ions (i.e., electrons are excluded from the layer) is formed in the vicinity of the plasma grid (PG). Such plasma with positive and negative hydrogen ions is called "double-ion plasma", and it could have strong influences on the formation mechanism of plasma meniscus.

We have developed the 2D3V PIC (Particle-in Cell) model[2)-5)] to analyze the profile of plasma density in the extraction region self-consistently with the charged particle dynamics. The model has been applied to the detailed analysis of extraction region in NIFS half-scaled R&D ion source. The model geometry used in the simulation is shown in Fig. 1. Figure 2 shows the density profile of the difference between before beam extraction and during beam extraction. The electrons compensate the decrement of the H^- density due to the beam extraction. The simulation result supports the qualitative explanation of the experimental results. We focus on the influence of the double-ion plasma on the electron loss along the field line on the density. The dependence on the electron loss probability and the thickness of the double-ion plasma from the PG surface along the extraction axis ($\tilde{y} = 40$) is shown in Fig. 3. The thickness of the double-ion plasma layer strongly depends on the amount of electron loss along the field line.

For further understanding of the formation mechanism and control of the plasma meniscus, more detailed modeling such as a 3D model and comparison with the experimental results are now underway.

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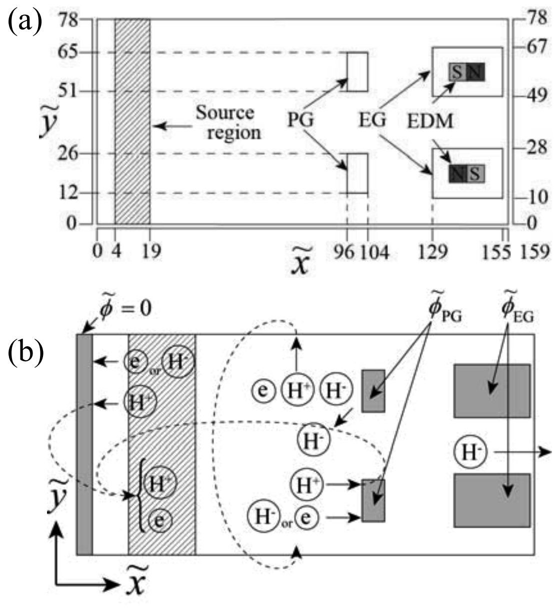

Fig. 1 Numerical model for the NIFS half-scaled R&D ion source : (a) The model geometry, (b) Boundary condition.

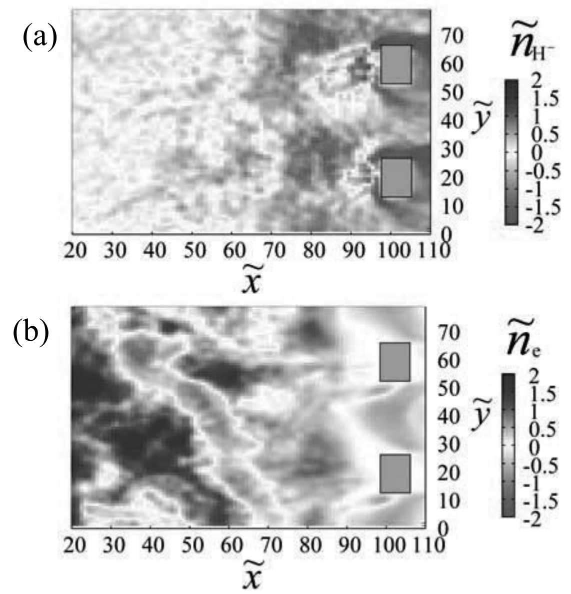

Fig.2 2D density profile of the difference between before beam extraction and during beam extraction: (a) H^- ions, (b) Electrons.

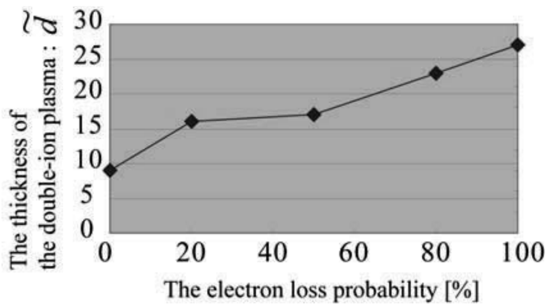

Fig. 3. The influence of the electron loss probability on the thickness of the double-ion plasma.