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

Hatayama, A., Wada, S., Hayami, T. (Keio Univ.),
Miyamoto, K. (Naruto Univ. Education),
Fukano, A. (Tokyo Metro. College of Indus. Technol.)

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.

In order to understand/optimize H^-/D^- production process, modeling/analysis of electron energy distribution function (EEDF) inside negative ion sources is indispensable. We are developing a numerical code which analyzes EEDF in tandem-type arc-discharge sources[1]. It is a full 3D kinetic Monte Carlo simulation code with the realistic source geometry and magnetic configuration. Coulomb collision between electrons is treated with "Binary Collision" model and inelastic/elastic collisions with hydrogen species are treated with "Null-collision (NC)" method. We have applied this code to the analysis of NIFS-R&D ion source, which is scaled down to a half size of the LHD sources. Figure1 shows the initial simulation result of the EEDF obtained by the EEDF code (under the discharge condition: P_{arc}= 50kW, V_{arc}= 90V, P_{H_2}= 0.25Pa). The average kinetic energy (temperature) of electrons from the EEDF is also plotted along the extraction axis as a function of the distance from the plasma grid/electrode(PG) in Fig.2. The results reasonably agree with the Langmuir probe measurement and reproduce important characteristics observed in the experiments, e.g., decrease in electron temperature towards the PG (magnetic filter effect).

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. We have developed the 2D3V PIC (Particle-in Cell) model[2] to analyze the potential structure in the extraction region self-consistently with the charged particle dynamics. The model has been applied to the detailed analysis of ion emissive surface. Figure 3 shows typical results of H^- density near the extraction hole for the case with the "volume" H^- production under the presence of a weak magnetic field parallel to the PE (Plasma Electrode). Relatively clear H^- emissive surface can be seen in this case.

Recently, in the NIFS half-scaled R&D ion source above, the following interesting experimental observations have been reported under the strong "surface" H^- production case with the Cs-seeding[3]: 1) Plasma layer almost only with H^+ and H^- ions (i.e., double ion plasma with only few electrons) is formed in front of the PE, and 2) the thickness of the double ion layer is relatively large (at least, it exists between 6.5mm and 12.0mm from the PE by Langmuir probe measurements). These double ion plasma characteristics possibly affect the potential structure and the resultant H^- ion emissive surface. Therefore, we start improving the above 2D3V PIC model and applying to NIFS half-scaled ion source. The detailed analysis of H^- /D^- ion emissive surface and comparison with the above "volume" H^- production case in Fig.3 is now underway.

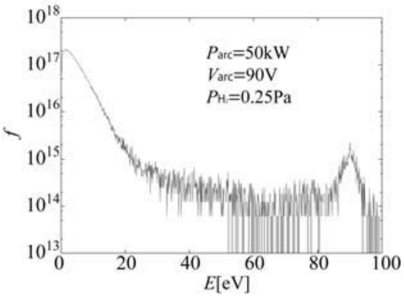

Fig.1 EEDF for NIFS half-sized R&D ion source calculated by the EEDF simulation code

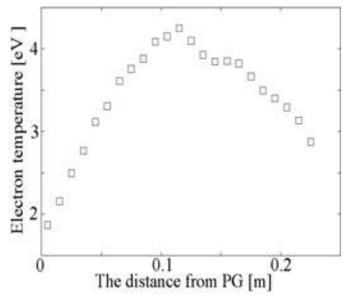

Fig.2 Average kinetic energy of electrons along the extraction axis as a function of the distance from the plasma grid

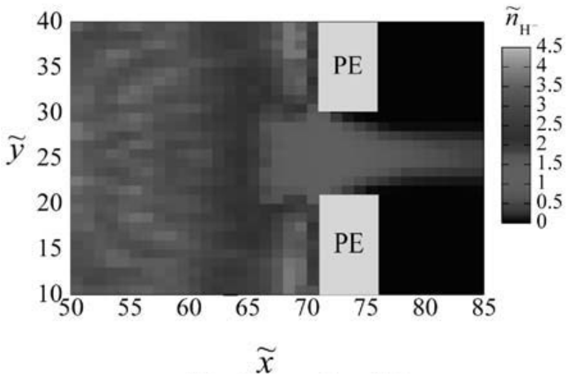

Fig.3 H^- density profile near the extraction hole of the plasma electrode.

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2) S. Kuppel, D.Matsushita, A.Hatayama and M.Bacal, J. Appl. Phys. **109**, 013305(2011).
3) K. Tsumori, *et. al*., *Super CCNB 2010*, Takayama, Gifu, Japan, (2010).