§5. Electron-Beam Control and Efficiency Improvement for Negative-Ion Accelerator

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Negative-ion beam injection is of significant importance in the plasma heating for large helical device (LHD) [1]. However, the acceleration efficiency of the negative-ion accelerator is limited by the electron flow which also causes damage and heat-loading problems on the electrodes. By eliminating the electron flow in the negative-ion accelerator, it can be expected to significantly improve the accelerator efficiency, reliability, and lifetime.

This research is an attempt to clarify the mechanism of electron current formation and to find a way for electron beam control, by using three-dimensional simulation. The simulation results will be compared with the experimental results obtained on LHD in order to give a guideline for electron-beam control and negative-ion efficiency improvement.

The commercially available simulation software “MAGIC” has been used, which is an electromagnetic, relativistic, particle-in-cell code widely used in plasma and particle-beam studies [2]. In the simulation, the negative-ion accelerator is modeled by a plasma grid (PG), an extraction grid (EG), and a ground grid (GG). In the three-dimensional space with predetermined electric and magnetic field distribution, the negative ions, the electrons, and the secondary electrons are traced time-dependently. The results are used to discuss about the electron behavior and negative-ion optics.

Figure 1 shows the typical particle distribution obtained by the simulation. The electrons are deflected by the deflection magnetic field and mostly absorbed by the extraction grid. However, the electron bombardment on the extraction grid causes secondary electrons, some of which are evidently accelerated by the main acceleration field and arrive at the ground grid.

In addition, the negative-ion trajectories are studied by the simulation. It has been observed that the divergence angle of the negative ions depends very much on the surface configuration of the ion source which is artificially determined by the simulation model in order to represent the source plasma. Therefore, it has been understood that, for a more realistic simulation, the model for the ion source has to be improved so that the ion divergence angles can be studied with higher accuracy.

In summary, three-dimensional simulation has been used to investigate the particle behavior in the negative-ion accelerator. The simulation results have indicated the possible production of secondary electron and have shown their trajectories. This simulation method is expected to be used for control of secondary electrons in future studies.

References
1) Tsumori, K. et al.: Rev. Sci. Instrum., 75 (2004) 1847.
2) Goplen, B. et al.: Comput. Phys. Commun., 87 (1995) 54.

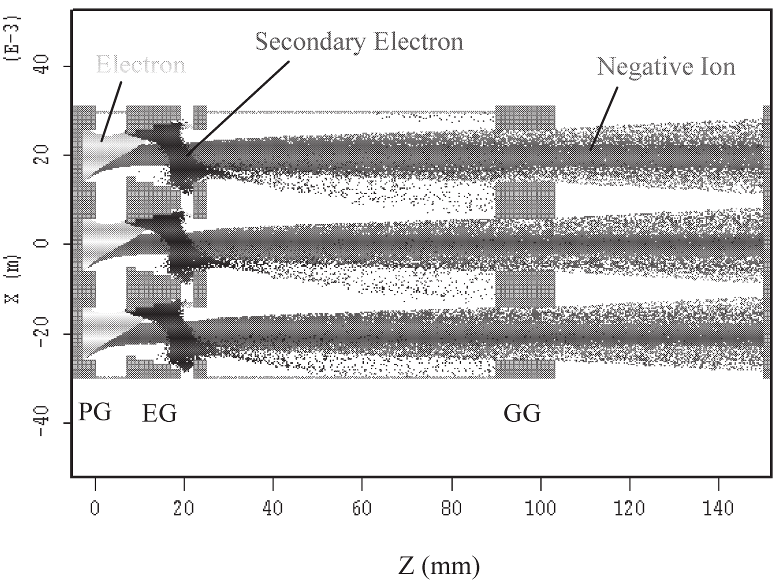

Fig 1. Particle distribution obtained in the simulation.