§4. Characteristics of Electron Beam Behavior in 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 simulations. The simulation results are 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]. The simulation results obtained earlier have indicated the possibility of secondary electron production on the electrodes. In the study reported below, we have turned our attention to the residual gas molecules which, under the bombardment of negative ions, may be ionized giving rise to free electrons in the acceleration region of the negative ions.

The simulation model is similar to the previous one, except for that the electron emission from the plasma source has been turned off, in order to observe the behavior of the electrons produced in residual gas ionization. In the simulation, the whole volume is filled with low density of hydrogen gas which has a certain ionization cross-section by the collision of the negative ions. Due to the complicated physical processes involved, the absolute value of collisional ionization obtained is not accurate. However, the purpose of the simulation is to observe the behavior of the electrons produced by the ionizations.

Figure 1 shows the typical particle distributions obtained by the simulation. It is observed from Fig. 1 that the electrons are produced on the pass of the negative ions. Those produced in the acceleration gap are quickly removed by the electric field and those produced in the drift region stay there for a long time. On the other hand, the positive ions produced by the ionizations are accelerated toward the plasma source.

In summary, three-dimensional simulations have been used to investigate the particle behavior in the negative-ion accelerator. The simulation results have indicated that the impact ionization of the residual gas molecules results in electron beam acceleration which may reduces the negative ion efficiency and leads to anode electrode damage and heat loading.

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

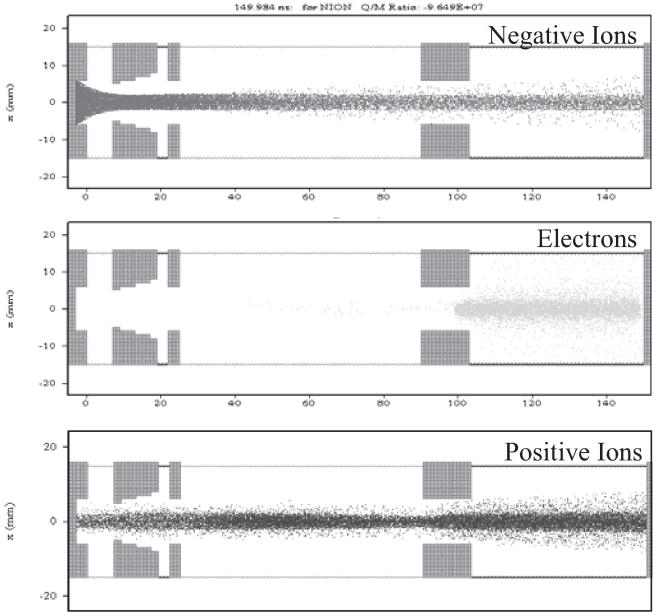

Fig. 1 Simulation results of negative ion, electron, and positive ion distributions.