§19. Study on Optimization of Gas Species and Thickness to Generate Au$^+$ Ion Beam with Tandem Accelerator for LHD-HIBP System

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In order to expand applied range of the heavy ion beam probe measurement on LHD, it is important to increase the probing beam current. One of a method of increasing the current is improvement of charge exchange efficiency at a gas cell in the tandem accelerator for LHD-HIBP[1]. The objective of this study is to research physics of atomic collision between Au$^-$ ion and atoms in a gas cell at the high voltage terminal with experimental and theoretical approaches.

It is difficult to carry out a charge exchange experiment in variations of gas species and gas pressure in the gas cell of LHD-HIBP. The measurement can be carried out at the tandem accelerator of Kobe University. The experiments for various gas species, gas pressure, and beam energy can be easily conducted at the accelerator. But the terminal voltage was limited to 150 kV because momentum of MeV Au ion is too large to be bent by a bending magnet, or the SW magnet. To conduct the experiments for the higher energy ion beams, a chamber was installed at 0 degree beam line in the present study. This allows detecting the Au$^+$ ions whose energy is up to 3.4 MeV because the chamber has a Faraday cup at small bent angle. The Au$^-$ energy is smaller than Au$^-$ of LHD-HIBP system (up to 6 MeV). So, a theoretical model for electron stripping and capture at a gas cell, which has the dependence of the cross sections on ion energy in collision, is constructed, then the values between accelerators such as cross sections can be compared with this theoretical model. Consequently, an Au$^+$ beam of LHD-HIBP can be optimized for plasma diagnostics.

In order to obtain some cross sections in collision, the gas thickness, *nl*, at the cell has to determined exactly. Gas pressure at the cell was measured with a pressure transducer, BARATRON, which can measure the absolute value (no sensitivity of gas species). Using these results, the absolute value of the gas thickness was calibrated for various gases.

Fig. 1 shows the experimental results of the Au$^-$ beam attenuation in some energy. The energy indicates the impact energy colliding with gas target. In case of this result Ar gas was used as target gas, and some kinds of gas were used other experiments. Exact beam current can be expressed by the rate equations. In this case normalized negative Au ion current, I/I_0, can be sufficiently approximated by the next equation.

$$I / I_0 = \exp(- \sigma\, n\, l), \qquad (1)$$

where σ is a total cross section, *nl* is gas thickness, and I_0 is Au$^-$ beam current at $nl = 0$. One can obtain the cross sections by fitting the above equation to these attenuation curves. The cross section is total cross section include singly and doubly ionization reaction. These values are shown in Fig. 2 and those values written in Ref. 2 are also presented. Our data are in good agreement with the data in Ref. 2. There is a small difference between these data for high energy ions.

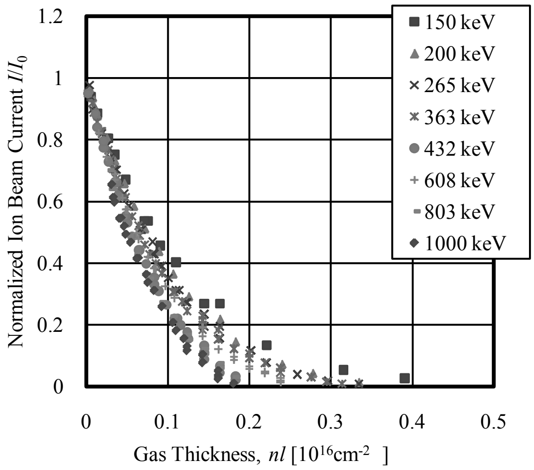

Fig. 1. Au$^-$ attenuation curves for some impact energies.

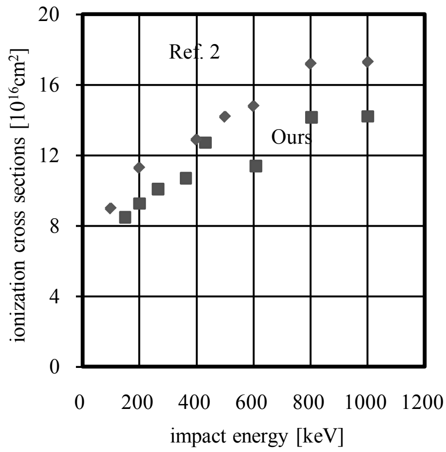

Fig. 2. Dependences of total cross sections and the coefficient on the impact energy.

Experiments to detect the positive Au beams were also conducted, and some data were presented in Ref. 3. But cross sections for the other ionization, recombination, and so on are not obtained in good precision. If the neutral particles can be detected, the cross sections can be determined. Optimizing gas thickness and/or species at the gas cell to increase Au$^+$ beam, an Au$^+$ beam current of LHD-HIBP can increase. Then, LHD-HIBP can be applicable for high density plasma diagnostics.

1) Ido, T. et al. : Rev. Sci. Instrum. 77, 10F523(2006)
2) Anna, M. M. S. et al. :Plasma Phys. Control. Fusion 51 (2009) 045007(9pp)
3) Taniike, A. et al.: Plasma Fusion Res. 5, S2087(2010)