§2. Plasma Simulation Experiments Using Versatile Highly Charged Ion Sources

Nakamura, N., Ohtani, S. (Univ. of Electro-Communications),
Kato, D., Sakaue, H.A.

Using highly charged ion (HCI) sources at the University of Electro-Communications (UEC) and NIFS, we have been obtaining atomic data of highly charged ions such as the cross sections of resonant recombination and ionization processes[1,2]. Those data are important as fundamental atomic data in non-equilibrium plasmas such as the peripheral plasma in fusion devices and the transition region in the sun's atmosphere. On the other hand, the purpose of the present study is to make more active contribution to the understanding of such non-equilibrium plasmas by obtaining experimentally simulated spectra emitted from HCIs interacting with electrons that have an arbitrary velocity distribution.

In the present study, a recently developed compact electron beam ion trap (EBIT), called "CoBIT"[3], is used. To obtain simulated spectra, the electron beam energy and current should be fast controlled whereas they are fixed in ordinary operation of an EBIT. Thus, at the beginning of this fiscal year, we improved the power supply system of CoBIT to control the electron beam energy and current. For example, Fig. 1 shows a function used to simulate a Maxwell-Boltzmann distribution. This function is so determined that the time period Δt when the electron energy lies between E and $E+\Delta E$ should be proportional to the Maxwell-Boltzmann distribution ($\Delta n / \Delta E$). By controlling the current at the same time, the electron current density is kept constant.

Fig. 2 shows a preliminary result obtained in a trial run. Both the spectra shown in the figure were obtained by observing highly charged Sn ions produced and trapped in CoBIT with a grazing incidence flat-field grating spectrometer. Sn was injected as a vapor by using an effusion cell. Fig. 2(a) was obtained with controlling the electron beam and current with the function shown in Fig. 1 (the simulated temperature was 400 eV) whereas Fig. 2(b) with an electron beam at a fixed energy of 400 eV. As shown in the figure, clear difference is found between them due to the difference in the electron energy distribution. To check the present experimental technique, test studies by observing temperature-sensitive lines are ongoing.

In addition to the observation of simulated spectra, measurements of the cross sections for the fundamental processes relevant to plasma are also performed. In particular, charge exchange cross sections for Xe^{q+} (q=10-25) + Li collisions was measured using an electron beam ion source, called NICE, at NIFS. To obtain the absolute value, calibration of the target density is ongoing.

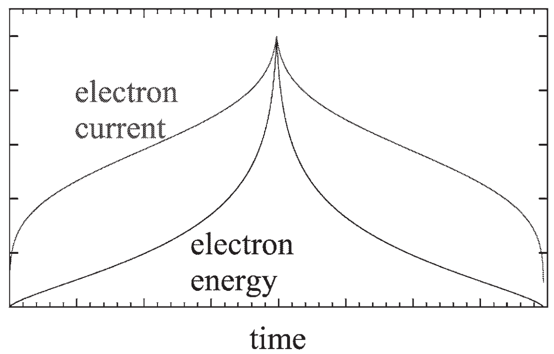

Fig. 1. Functions used to control the electron beam energy (blue) and current (red) as to simulate a Maxwell-Boltzmann electron velocity distribution.

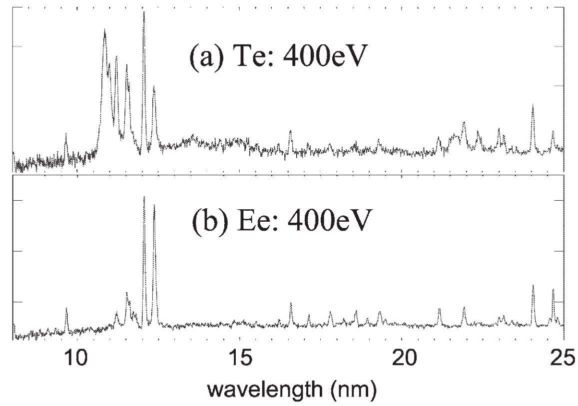

Fig. 2. EUV spectra of highly charged Sn ions observed with CoBIT. (a) The electron energy was fast-controlled with a function shown in Fig. 1. The simulated temperature was 400 eV. (b) The electron energy was fixed at 400 eV.

1) Hiroyuki A. Sakaue, Atsunori Danjo, Kazumoto Hosaka, Daiji Kato, Masahiro Kimura, Atsushi Matsumoto, Nobuyuki Nakamura, Shunsuke Ohtani, Makoto Sakurai, Hiroyuki Tawara, Ichihiro Yamada, Masuhiro Yoshino, J. Phys. B 37 (2004) pp. 403-415
2) Nobuyuki Nakamura, Anthony P. Kavanagh, Hirofumi Watanabe, Hiroyuki A. Sakaue, Yueming Li, Daiji Kato, Fred J. Currell, and Shunsuke Ohtani, Phys. Rev. Lett. 100, 073203 (2008)
3) Nobuyuki Nakamura, Hiroyuki Kikuchi, Hiroyuki A. Sakaue, and Tetsuya Watanabe, Rev. Sci. Instrum. 79, 063104 (2008)