§5. Development and Application of Ion Sources Excited by a DC High-Current Electron Beam

Ohgo, T.(Fukuoka Univ. of Edu.)
Hara, T.(Toyota Technological Institute)
Hamagaki, M.(RIKEN)
Otsuka, M.(Honorary Prof. of Nagoya Univ.)
Fukumasa, O.(Yamaguti Univ. Eng.)
Kuroda, T

A DC high-current electron beam gun has been investigated for development of new type ion source, which has optimum energy for ionizing inert gas atoms by collision. Therefore, most of electrons can contribute to ionization of atoms. It is expected to produce efficiently a high density plasma by using this type of the e-beam gun.

In last year, we reported on measurements of electron density and temperature by the Thomson scattering with a YAG laser. High density plasmas of 10^{13} to 10^{14} cm^{-3} with the electron temperature of 0.42 to 10 eV were obtained.

In Fig.1, the DC high-current e-beam gun is schematically shown. It consists of four sections: (1) the glow discharge region (K - S), (2) the electron acceleration region (S - A_1), (3) the ion production region (A_1 - A_2), and (4) the plasma region (A_2 - T).

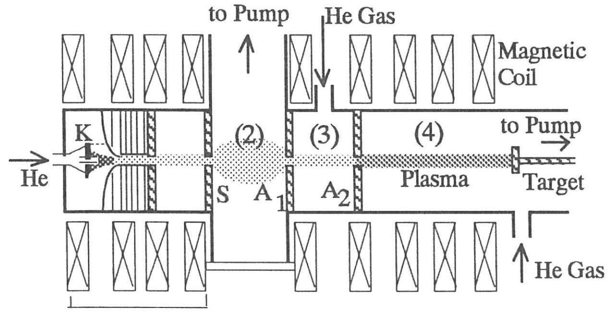

Fig.1. Schematic diagram of a DC high-current electron beam gun.

In order to see how efficient in plasma production this equipment is, we estimated the plasma density along three assumptions as follows. (see Fig.2)

1. The electron beam in the region(4) spend all energy in ionizing the helium atoms during the plasma column.
2. The loss of the helium plasma in the region (4) is only from the both end of the plasma column to the target and to the electrode A_2.
3. The loss of the plasma ion is only due to the ion sarturation current.

Thus the rate equation of the plasma density is given by

$$\frac{d(n_e L)}{dt} = n_b v_b \frac{E_b}{E_i} - \frac{2I_{is}}{q} = 0, \qquad (1)$$

where n_e is the elestron density, L the length of the plasma column, n_b the electron beam density, v_b the velocity of the electron beam, E_b the energy of the electron beam, E_i the ionization energy of the helium atom, I_{is} the ion saturation current density of the plasma and q is the ion charge.

On the other hand, the ion saturation current density I is is given by

$$I_{is} = 0.61 q n_e \left(\frac{kT_e}{m_i}\right)^{\frac{1}{2}}, \qquad (2)$$

where k is the boltzman coefficient, T_e the electron temperature and m_i the ion mass. After substituting eq.(2) for eq.(1), n_e can be estimated.

Since at the high pressure the plasma fade out in front of the target by recombination, the estimation is made on the pressure of 6.7 mTorr of the helium gas. The electron density is estimated to be about 1.4 x 10^{14} cm^{-3} at the beam current of 19 A and the acceleration voltage of the electron beam of 100 V. The electron density measured was 3.2 x 10^{13} cm^{-3}. It is indicated that the plasma excited by the electron beam is produced in high efficiency of larger than 30% to all the electron-beam eneregy.

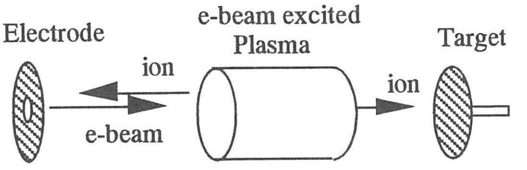

Fig.2. A model of the plasma production excited by DC high-current low-energy electron beam.