PRESENT STATUS ON THE DEVELOPMENT OF A BEAM PLASMA HEAVY ION SOURCE (BPHIS-1) AND THE FUTURE PROGRAM

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1. Introduction

Present status on the development of a beam plasma heavy ion source (BPHIS-1) and the program in future are described. Up to now, a Pierce-type electron gun with a large concave LaB_6 cathode, a plasma chamber and an ion-extraction system have been completed. Beam currents of argon ions as functions of several parameters, the extraction voltage, the extraction geometry and gas pressure, have been measured.

The plasma-sheath distance and the shape of the ion-emission surface, i.e., the plasma surface, are obtained by analyzing the experimental results and also by computer simulation.

BPHIS-1 will be changed to an ion source of an ECR-type, in which an electron beam is to be injected.

2. Experiments and theoretical analysis

The construction of BPHIS-1 is shown in Fig. 1. BPHIS-1 is composed of an electron gun of a Pierce-type, a plasma chamber and an extraction system. The electron gun[1] possesses an LaB_6 cathode with 20 mm concave radius and 30 mm diameter. The electron currents emitted from the LaB_6 cathode are higher than 200 mA when the cathode is heated to its operating temperature above 1300°C. Neutral gas is introduced from a gas inlet into the plasma chamber with an external solenoid. The primary electron beam accelerated to several keV bombards the neutral gas so that a plasma is generated in the chamber. Stripping of electrons takes still more place in the plasma chamber due to a beam-plasma interaction. In this condition, ions are extracted from the plasma chamber.

Fig. 2 shows the results of experiments; the ordinate and the abscissa designate the normalized ion currents and the extraction voltage, respectively. The experiment shows that the normalized ion current varies in proportion as the minus second power of the distance between the electron collector and the ion extractor. Therefore, it is concluded that the relation of normalized ion currents and the distance between the electrodes obeys the current limited by space-charge. The current I is given by

$$I=\frac{4}{9}\varepsilon_0\left(\frac{2Ze}{m_i}\right)^{1/2}\frac{V_i^{3/2}}{d_s^2} \quad ,$$

where ε_0 is the dielectric constant for vacuum, Z the effective charge state, m_i the ion mass, V_i the extraction voltage, and d_s the sheath distance. Under the assumption that the effective charge state Z is constant and independent on extraction voltage, the experimental data leads results shown in Fig. 3.

In order to evaluate the position and the shape of the plasma surface at the extraction system, and to obtain ion beam trajectories, computer simulation has been performed by relaxation techniques [2] on a matrix with a maximum size of 1815 points in following procedure:

(1) Geometry of the electron collector and the ion extractor, and voltages applied on each electrode are introduced. The voltages at points within the extraction system are computed by iteratively solving Laplace's equation expressed in difference forms.

(2) By solving the equation of the Lorentz force described in different forms, electron trajectories are obtained.

(3) New potential, which is thought over the effect of space-charge on the electron trajectories, is determined by solving the Poisson's equation.

(4) Ions are emitted from the surface determined by potential of the space-charge.

Results of computer simulation are shown in Fig. 4 and Fig. 5.

3. Results

Fig. 3 indicates that the sheath distance increases with the increase of applied negative voltage. The lines in Fig. 3 denote the sheath distances which are obtained by estimating results of computer simulation. What is the conclusion from comparing the experimental results with the simulated results is an agreement of a tendency between both results and no absolute agreement.

As the voltage applied on the electron extractor varies, a change of sheath distance and that of the plasma surface are shown by the experiments and computer simulation so that the conditions to get beam quality were obtained.

4. Future program

In next experiments, the extracted ions will be analyzed by a bending magnet. It is hoped that we can study the change of charge state distribution with the distance between the plasma surface and the ion extractor.

To obtain high charge states and strong beam intensity, the following plans are considered: the plasma chamber will be changed to magnetic mirror, and a plasma trapped between the magnetic mirrors will be heated by an induced microwave power.

References

1) T. Shintake, K. Ohba, M. Matoba, and A. Katase: Jpn. J. Appl. Phys. 20 (1981) 341

2) J.E. Boers: IEEE Trans. Elect. Dev. ED-12 (1965) 425

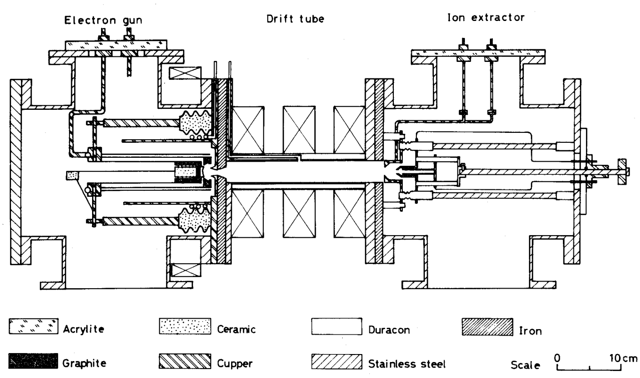

Fig. 1 Cross-section view of the beam plasma heavy ion source (BPHIS-1)

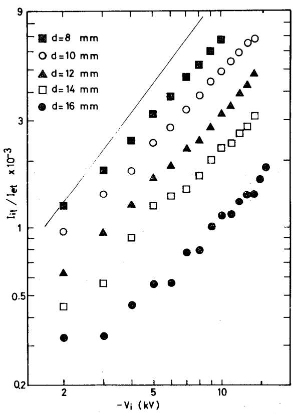

Fig. 2 Normalized ion current versus the extraction voltage

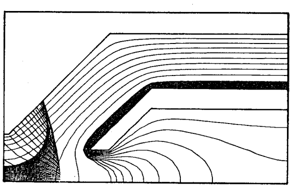

Fig. 4 Equipotential lines and electron trajectories

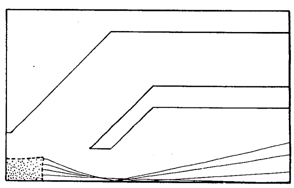

Fig. 5 Plasma surface and the ion trajectories

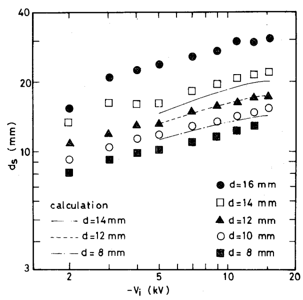

Fig. 3 Sheath distance versus the extraction voltage