CHARACTERISTICS OF AN ECR-EB HYBRID-TYPE MULTIPLY-CHARGED ION SOURCE

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1. Introduction

An ECR plasma can be applied to a multiply-charged heavy ion source. It has been pointed out by the authors that a high electron temperature would be necessary in addition to a high electron density and a long confinement time of ions, in order to obtain high-yield multiply-charged ions with an ECR plasma-type ion source [1,2].

The electron temperature easily becomes several tens of keV in an ECR plasma. However, it is difficult to produce a homogeneous hot-plasma at a high gas pressure only by the microwave supply. The operating pressure of an ECR plasma-type ion source will depend on the microwave frequency, the microwave power, the magnetic configulation, the magnetic field strength, the shape of the cavity, etc.

In this report, a plasma heating has been performed by the injection of an electron beam into an ECR plasma. It is the purpose to investigate a new hybrid-type ion source in combination of the ECR heating and the electron beam injection.

2. Experimental apparatus

The schematic diagram of the experimental apparatus is shown in Fig. 1. An ECR plasma is generated in the cavity chamber of 16 cm long and 17 cm in diameter. The magnetic field by two coils forms a mirror configulation with a mirror ratio of 3.7 and the maximum field strength of 1.1 kG. The 2.45 GHz microwave power is supplied by a magnetron (1.3 kW).

A magnetron injection gun, of which cathod is made of 0.5 mmϕ W wire, is placed on the opposite side of the chamber to ion extraction electrodes. The electron beam of 520 eV and 1.3 A is injected into the cavity chamber.

Ions produced in a plasma are extracted into a drift tube, and their charge states are analyzed by a mass spectrometer [1]. X-rays emitted from the plasma can be measured by a pure Ge solid state detector, which is placed about 150 cm apart from the chamber.

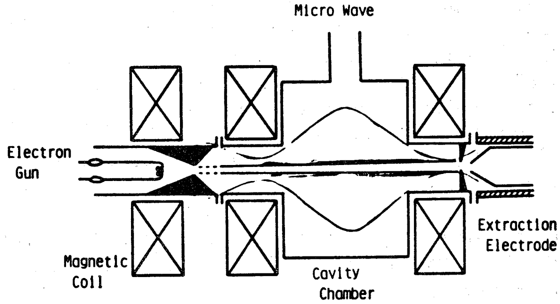

Fig. 1. Experimental apparatus.

3. Results and discussion

The density and the temperature of hot electrons in plasma can be estimated from the measurement of the bremsstrahlung X-ray spectrum. Figure 2 shows the gas-pressure and the microwave-power dependences of these plasma parameters, where argon plasma was generated only by the microwave. As is shown in this figure, both parameters of the ECR plasma decrease as the gas pressure exceeds about 1.0 $\times 10^{-4}$ Torr. On the other hand, the intensity ratio of Ar^{2+} ions to Ar^{+} ions extracted from the plasma became larger than 1.0, in the gas pressure region of $4.5 \sim 6.0 \times 10^{-5}$ Torr. But at the gas pressure of 2.6×10^{-4} Torr, the ratio was smaller than 0.1.

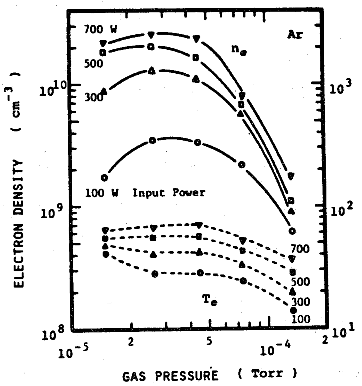

Fig. 2. Pressure- and power-dependences of electron density and temperature in an ECR plasma.

These experimental results may be attributed to that the plasma heating takes place only in the surface region at a high gas pressure. Namely, this unhomogeneity would cause the decrease of average electron density and temperature.

In order to restrain the decrease of the density and temperature, an electron beam was injected into the ECR plasma. The electron-beam-injection experiments were carried out with a xenon gas at first. The temperature variation in the range of $10 \sim 30$ keV can be clearly observed by the intensity of K_α line (29.6 keV). Typical X-ray spectra are shown in Fig. 3, where the notations "ECR" and "ECR-EB" represent the X-ray spectrum from the plasma produced only by the microwave and by both the microwave and the electron beam, respectively.

It is recognized that the electron density increases by the electron beam injection, because the X-ray intensity nearly corresponds to the electron density. The fact that the characteristic X-ray intensity of "ECR-EB" is much higher than that of "ECR" means a remarkable increase in the electron temperature. From the X-ray spectra, the temperature was estimated to be 13 keV in case of "ECR", and 23 keV in case of "ECR-EB". It has been also convinced that the temperature could increase up to 20 keV at the gas pressure of 2.4×10^{-4} Torr, where the temperature of "ECR" was so low that X-rays could not be emitted.

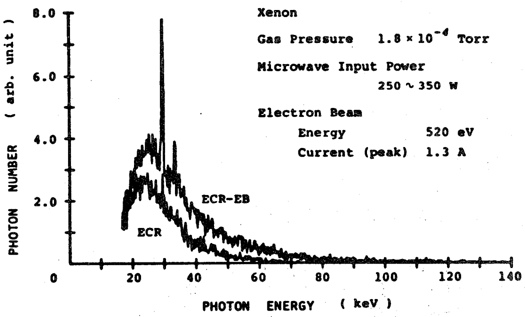

Fig. 3. X-ray spectra emitted from ECR plasma and EB-injected ECR plasma.

It is expected that a higher current of multiply-charged ions can be obtained by a hybrid-type ion source in combination of ECR heating and electron beam injection.

References

[1] N. Abe, K. Oda, T. Yamamoto, M. Kawanishi ; Jpn. J. Appl. Phys. 19 (1980) 149.
[2] K. Oda, N. Abe, T. Yamamoto, M. Kawanishi ; Proc. 4th Symp. ISAT (1980), p.19.