The Effect of an Electrode in Plasma Chamber of RIKEN 18GHz ECRIS (Electron Cyclotron Resonance Ion Source)

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Abstract

We observed the enhancement of the Xe^{20+} beam intensity from the RIKEN 18GHz electron cyclotron resonance ion source(ECRIS) when using the electrode which was installed in plasma chamber of ion source. In order to study the effect of electrode to ECR plasma, We measured high energetic bremsstrahlung X-ray and beam intensity of Xe^{+20} when changing electrode position and supplied bias voltage. We observed that yield and slope of high energetic X-ray spectra and beam intensity of charged ions are strongly dependent on the negative bias voltage of electrode and its position.

1 Introduction

In the last decade, electron cyclotron resonance ion sources (ECRIS) have been developed from a complex prototype to compact and high-performance ion sources for accelerators and atomic- physics experimental apparatus [1]. They can produce very highly charged ion beams from most elements of the periodical table. It is well known than highly charged ions are efficiently yielded mainly through the successive ionization process. Therefore, to obtain higher beam intensities, it is crucial to optimize the confinement time of the ions in the electron cloud and to increase the density of ionizing electrons. To fulfill These requirements many laboratories have made efforts by using various methods [1]. One of these methods is to install a biased or floating electrode into the plasma chamber of the ion source [1]$\sim$ [7]. Recently, we successfully applied this method to the RIKEN 18GHz ECRIS and observed strong enhancement of beam intensity of highly charged argon ions [4]. In this experiment we observed that when we placed the electrode near the RF injection region,the beam intensity decreases with increasing the negative bias voltage, and the best results were obtained at 0V. On the other hand when we placed the electrode far from the RF injection region, we observed the beam intensity increases with increasing the negative bias voltage. The result of this experiment means there is the two different phenomena when using the electrode at different position.

In order to understand these phenomena, we need new experiments and more systematical study. then we measured bremsstrahlung X-ray emission from ECR plasma. It is well known that the measurement of bremsstrahlung X-ray emission is a good tool to study the kinetic energy distribution and density of electrons in plasma [3]. In this paper, we report the result of X-ray measurements when changing the electrode position and bias voltage. From a viewpoint of the plasma phenomenon, it is useful to understand the effect of electrode.

2 Description of 18GHz ECR,Electrode and experiment set up.

The design and performance of the RIKEN 18GHz ECRIS without using the biased electrode we described in ref 8. Fig. 1 shows the cross sectional view of the RIKEN 18GHz ECRIS with a stainless steel electrode. The diameter and thickness of the electrode are 18 and 1mm,respectively. The negative biasvoltage is applied between the electrode and plasma chamber as shown in fig. 1. It can also use the electrode at the floating potential by disconnecting it from the electric power supply. The electrode are placed on axes of the plasma chamber. The axial position of the electrode is remotely controlled with accuracy of 0.1mm.

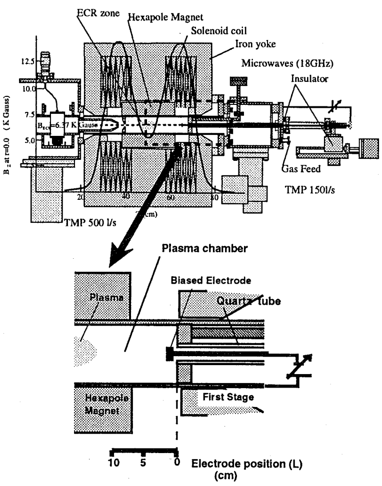

Fig. 1 Cross sectional view of RIKEN 18GHz ECRIS

For all elements heavier than carbon, usually gas mixing is used to obtain the higher intensity of highly charged heavy ions. In the present case, we used the oxygen gas as a mixing gas to produce Xe ions. The plasma chamber wall is covered up with a thin aluminum tube (of thickness 1mm). The aluminum oxide surface emits several secondary electrons per primary electron impact, which helps to increase the plasma density [8].

For measurement of X-ray, we used the NaI(Tl) scintillation counter placed at downstream of ECRIS. The size of NaI(Tl) scintillation counter was 2 inch in diameter and 2inch in length. The lead collimator (hole of 1mm diameter and the 50 mm length) was set in front of the counter. In order to minimize the back ground, the counter was covered by the lead sheet (thickness of 4mm).It was set on the beam line toward the plasma camber of the back side to the analyzing magnet.The distance from the counter to the plasma center was 2m.

3 Result and Discussion

3.1 Beam intensity with the electrode

We already observed the enhancement of beam intensities of highly charged heavy ions. Figure 2. shows the summary to the highest beam intensity of the gaseous elements. The closed and open circles are the results with and with out using the electrode, respectively. The beam intensity of highly charged ions strongly enhanced with using the electrode.: e.g. 1mA of Ar^{8+},300eμA of Ar^{11+},200eμA of Kr^{15+},12eμA of Xe^{30+}. [10][11].

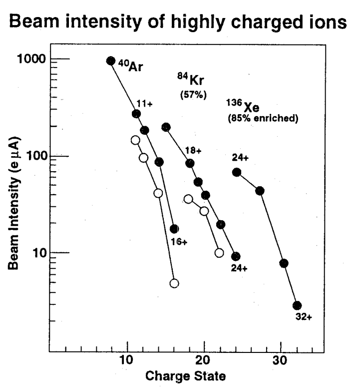

Fig. 2 Beam intensity of highly charged ions from gaseous elements.Open and closed circles are the results without and with using the disc.

We checked the effect of electrode to produce Xe^{20+} ions,We measured the beam intensity of Xe^{20+}. The ion source was tuned for producing Xe^{20+} ions at the bias voltage of 0V. Gas pressure of plasma camber was 7×10^{-7} Torr. The maximum and minimum magnetic field strength of mirror magnetic field were 1.4 and 0.47 T, respectively. Extraction voltage was 10kV. Injected microwave power was 600W. Best result of 100eμA was obtained at the electrode position, L=3.25cm. The beam intensity of Xe^{20+} was 60eμA when we do not use the electrode at 10kV extraction and 600W RF power.

We also observed the oscillation of beam intensity same as that for Ar^{11+} as descried in ref.11. The beam intensity increases with increasing the negative bias voltage at L=6.55cm.On the other hand the beam intensity decreases with increasing the negative bias voltage at L=3.25.In the case of Xe ions, the dependence of bias voltage is strongly dependent on the position of electrode. On the other hand the beam intensity decreases with increasing the negative bias voltage. In the case of Xe ions, the dependence of bias voltage is strongly dependent on the position of electrode.

3.2 X-ray measurements

To investigate the effect of the electrode, we measured the X-ray emitted from the ion source using the NaI(Tl) scintillation counter to estimate how the kinetic energy distributions of electron in ECR plasma change. Simultaneously, we measured the beam intensity of highly charged Xe ions. The ion source was tuned for producing Xe^{20+} ions at the bias voltage of 0V. Gas pressure of plasma camber was 7×10^{-7} Torr. The maximum and minimum magnetic field strength of mirror magnetic field were 1.4 and 0.47 T, respectively. Extraction voltage was 10kV. Injected microwave power was 200W. For the test experiment, we did not change these parameters except negative bias voltage and position of electrode. Figure. 3. shows the beam inten-

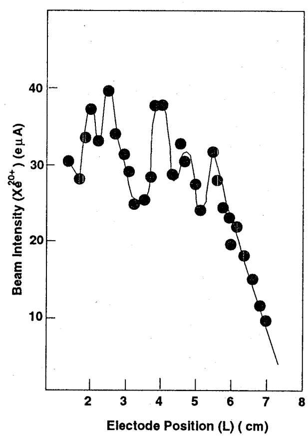

Fig. 3 Beam intensity of Xe^{20+} as a function of the electrode position at the RF power of 200W

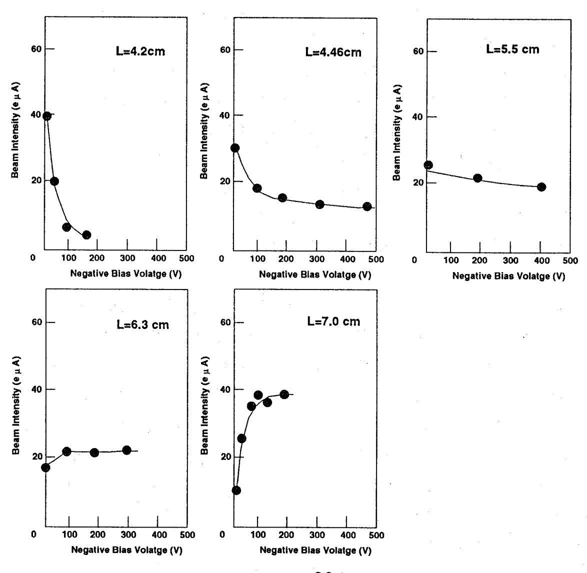

Fig. 4 Beam intensity of Xe^{20+} as a function of negative bias voltage for several electrode position.

sity of Xe^{20+} as a function of electrode position at bias voltage of 0V. The tendency was same as that at micro wave power of 600W. Figures. 4. shows the beam intensities as a function of negative bias voltage at various electrode position. At smaller L, the beam intensity decreases with increasing the negative bias voltage. In the region of L 5cm, the beam intensity became constant. The beam intensity increases with increasing the negative bias voltage at L=7cm.

Figure. 5. shows the X-ray spectra at several electrode positions. At the electrode position of L=4.46cm, the slope of X-ray spectra become gentler with increasing the negative bias voltage.Relatively low energetic X-ray($\leq$150keV) decreases with increasing the bias voltage. On the other hand,the high energetic X-ray($\geq$200keV)increases. It mean that the number of high energetic electron become larger with increasing the negative bias voltage. At L=5.88cm. both of total number and slope of X-ray spectrum does not change so much.At this position, as mentioned above, the beam intensity of Xe^{20+} also does not change. At L=7cm, the slope of the X-ray spectra does not change, on the other hand, total number of X-ray increases with increasing the negative bias voltage. It seem that the density of electrons increases with increasing the bias voltage. Unfortunately, we could not measure the low energetic electrons, which is smaller than several ten keV. To clarify the effect of electrode on the electron density, we need the further investigation.

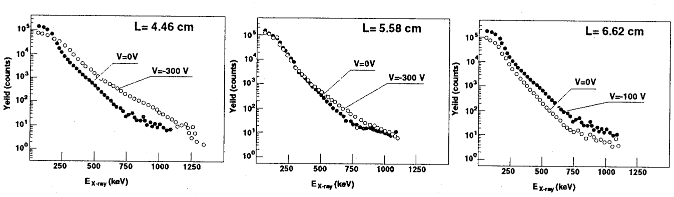

Fig. 5 X-ray spectra emitted from the ion source at the electrode position (L)of 4.46,5.58and 6.62cm

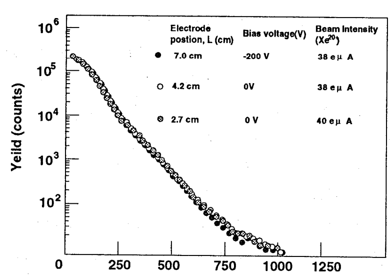

Fig. 6 X-ray spectra emitted from the ion source when obtaining the best result.

Figure. 6. shows the X-ray spectra measured when obtaining the best results using the electrode.It can be seen that these three spectra are same slope and total yield. From these results of X-ray spectra and beam intensities of Xe ions, it seems that the optimized distribution of high energetic electrons exists to obtain the best results.

4 Conclusion

We measured the bremsstrahlung X-ray and beam intensities of highly charged ions from RIKEN 18GHz electron cyclotron resonance ion source as a function of negative bias voltage supplied to electrode. We observed that the electrode strongly affects the distribution of high energetic electrons in the plasma. ,i.e.; near the microwave injection side, the number of high energetic electron ($\geq$200keV) increases with increasing the negative bias voltage. At distance of 7$\sim$10cm from it, total number of electrons increases with increasing the bias voltage. In this experiment we observed how the electrode effect ECR plasma, and how change the beam intensity when using the electrode, this result is helpful to how use the electrode effective.

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