DEVELOPMENT OF RIKEN 18 GHZ ECRIS

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Abstract

We have constructed and tested the RIKEN 18 GHz ECRIS to extract various ions. We successfully obtained the intense beams of highly charged ions from gaseous elements, organic metallic compounds (by MIVOC method), and solid materials.

1. INTRODUCTION

The intense beams of medium mass heavy ions, mainly metallic ions, has become one of the major requests of users in RIKEN Accelerator Research Facility. For satisfying such requests, a new ECRIS is demanded as an external ion source of the RILAC (Riken heavy Ion Linear ACcelerator)[1]-Ring cyclotron accelerator complex. This ECRIS is also required for the Radioactive Ion Beam Factory (RIBF) project, in which it is aimed to supply various unstable nuclei beams to experiments in various fields[2].

According to the scaling law proposed by R. Geller, the beam intensity increases with the micro wave frequency and magnetic field strength of ECRIS.[3] Therefore, we have chosen the micro wave frequency of 18 GHz for the new RIKEN ECRIS which is connected to a new RFQ linac and used as a new injector of the RILAC[4].

In this paper, we present the description of the 18 GHz ECRIS (Section 2) and its performance in producing multi-charged ions from gaseous elements (Section 3) and from solid materials (Section 4). Especially, we report the results of the metallic ion production like Fe, Ni, etc. using the so-called MIVOC method in Section 4.

2. DESCRIPTION OF RIKEN 18 GHz ECRIS

Figure 1 illustrates the design of RIKEN 18 GHz ECRIS. A single 18 GHz, 1.5 kW klystron supplies RF power to the source. The axial confinement of the plasma is obtained by two solenoid coils which form the magnetic mirror. The source is completely enclosed by an iron yoke in order to reduce the current of the solenoid coil. The maximum power consumption is 140 kW. The mirror ratio has a nominal value of 3.0 with B_{max} ~1.4 T and B_{min}~ 0.47 T. To optimize the radial confinement of the plasma, we use a hexapole magnet which has 36 segments and is made of Nd-Fe-B permanent magnet. The outer diameter (OD) and inner diameter (ID) are 180 mm and 80 mm, respectively. The field strength at the surface of magnets is about 1.4 T. To protect the hexapole magnet from demagnetization by

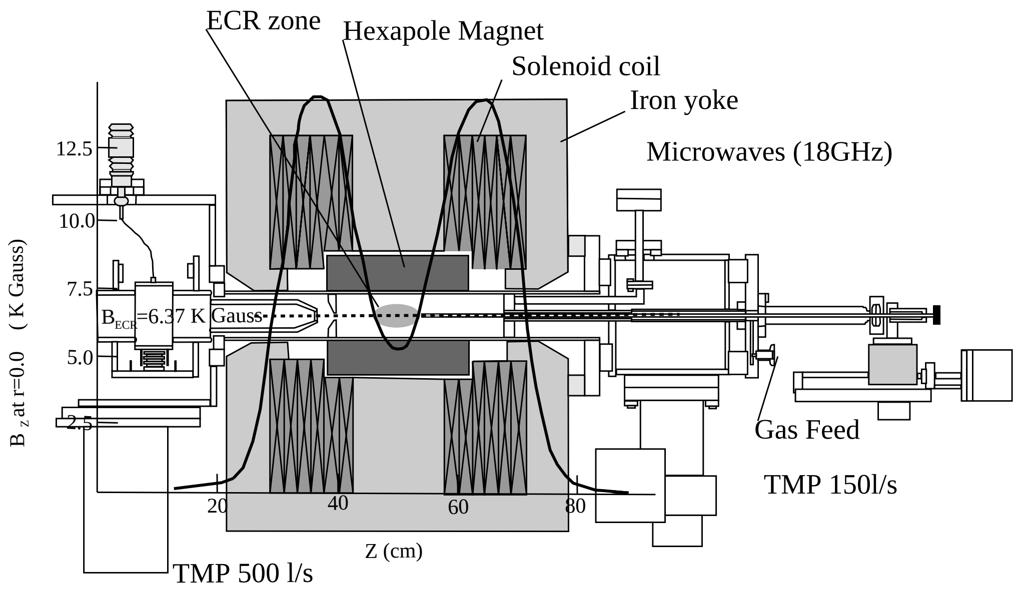

Fig.1. Cross sectional view of the RIKEN 18 GHz ECRIS.

high temperature, a water-cooled plasma chamber (ID= 74 mm, OD= 80 mm) has been constructed. A water-cooled hexapole housing also protects the permanent magnet from high temperature caused by the solenoid coil.

High vacuum of the plasma chamber is essential to produce the intense beams of highly charged ions. The effect of recombination of the ions can not be neglected in low vacuum. To minimize the recombination, the plasma chamber is evacuated with two turbo-molecular pumps (500 l/s and 150 l/s). The ultimate pressures of the plasma chamber and of the extraction stage are in the order of 10^{-8} Torr.

3. PERFORMANCE FOR GASEOUS ELEMENTS

Figure 2 shows the beam intensities of highly charged ions produced from gaseous elements. The beam intensities of 160 and 130 eμA for Ar^{11+} and O^{7+} were easily obtained. The typical gas pressures of plasma chamber and extraction stage were 1.0×10^{-6}, and 9×10^{-7} Torrs, respectively. The extraction voltage was 15 kV.

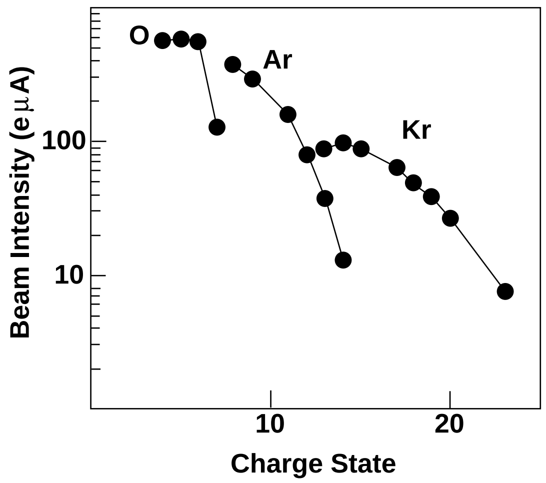

Fig.2. Charge state distributions of highly charged ions from gaseous elements.

It was observed that the intensities of highly charged ions were dramatically enhanced by coating the surface of the plasma chamber with aluminum oxide[7,8]. It is due to the increase of the number of secondary electrons emitted secondary by the electron impact. Very recently, Grenoble group has used a plasma chamber made of aluminum instead of stainless steal or copper and succeeded in the production of intense beams of highly charged heavy ions[9]. Both methods have been used in many laboratories. However, they still have a disadvantage in long-term operation, which is always necessary in RIKEN accelerator research facility, and in cost performance. The duration of the coating effect is about 2 or 3 months and it is needed to coat it again. The fabrication of plasma chamber with aluminum is usually difficult compared to the stainless steel chamber. From this point of view, we use an aluminum tube to cover the inner wall of plasma chamber. It is much easier than to construct a whole plasma chamber with aluminum. Figure 3 shows the obtained beam intensities of argon and krypton ions. The extraction voltage is 10 kV. Open and closed circles show the beam intensities with using a tantalum tube and an aluminum tube, respectively. We only need the RF power of 400 W to obtain the result shown in Fig.3 by using aluminum tube[9].

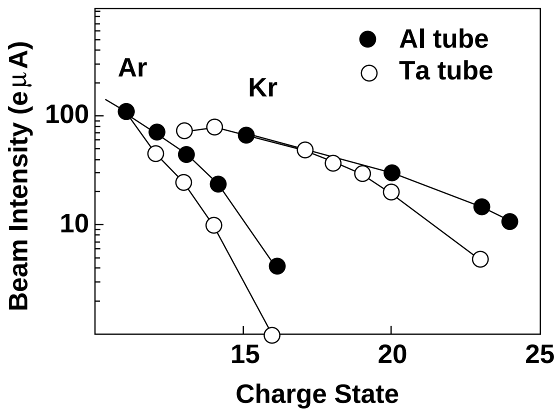

Fig.3. Charge state distribution of Ar and Kr ions. Open and closed circles represent the results obtained with a Ta and Al tube, respectively.

4. METALLIC IONS

4-1 MIVOC method

For the production of metallic ion beams by ECRIS's, several methods have been developed[10-12]. One of the methods is the so-called MIVOC (Metal Ion by VOlatile Compounds) method [11,12]. Organic metallic compounds are used in a high vapor pressure (i.e.10^{-3} mbar) to transform the metal into its gaseous state at room temperature. As reported in ref. 12 the main drawback of the MIVOC method is the contaminating the plasma chamber by carbon. In order to minimize this drawback, the plasma chamber wall is covered with the thin aluminum tube as described in the previous section. The compound chamber is attached to the gas feed with the regulation valve to control floating rate. Figure 4 shows the beam intensities of highly charged Fe, Ni and Ru ions produced respectively from $Fe(C_5H_5)_2$, $Ni(C_5H_5)_2$ and $Ru(C_5H_5)_2$ at the extraction voltage of 10 kV. The typical gas pressure of the plasma chamber and extraction stage were 1.5×10^{-6} and 5×10^{-7} Torrs, respectively. The RF power was about 300 ~ 500 W. The typical beam intensity of Fe^{13+}, Ni^{13+} and Ru^{16+} were 80, 60 and 30 eμA. As the Ru has the very high melting point of ~2450 ˚C, it is very difficult to obtain intense beam of highly charged Ru ions by other methods.

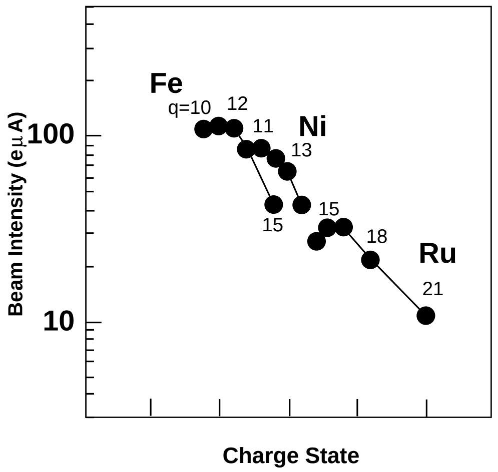

Fig.4. Charge state distributions of Fe, NI, and Ru ions using MIVOC method.

4-2 Ta ions

In order to produce highly charged Ta ions, we inserted a Ta-rod (the diameter is 2 mm) to the plasma directly. Figure 5 shows the best results for Ta ions at the maximum extraction voltage of 14 kV. The beam intensity of Ta^{20+} was 32 eμA. We also measured the dependence of beam intensity on the extraction voltage. Figure 6 shows the beam intensity of Ta^{20+} as a function of the extraction voltage. The beam intensity was found to be proportional to $V^{1.5}$ (dashed line), following the Child-Langmuir law, where V is the extraction voltage.

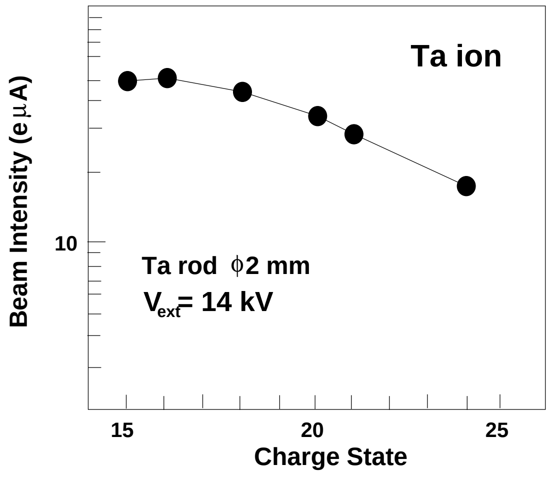

Fig.5 Charge state distribution of Ta ions at the extraction voltage of 14 kV

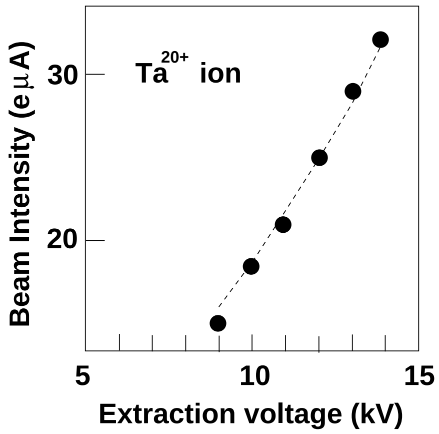

Fig. 6. Beam intensity of Ta^{20+} as a function of extraction voltage.

5. CONCLUSION

We have constructed and tested the RIKEN 18 GHz ECRIS to extract various ions. We successfully obtained the intense beams of highly charged ions(160eμA of Ar^{11+}, 80eμA of Fe^{13+}, 32eμA of Ta^{20+} etc.) from gaseous elements, organic metallic compounds (by MIVOC method), and solid materials.

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