RECENT DEVELOPMENT OF ECR ION SOURCES AT RCNP*

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Abstract

At Research Center for Nuclear Physics (RCNP), Osaka Univ., An 18 GHz superconducting ECRIS has been installed to increase beam currents and to extend the variety of ions, especially for highly charged heavy ions which can be accelerated by RCNP AVF cyclotrons. The production development has been performed and several ions like B, C ~ Xe have been obtained successfully by gas mixing or MIVOC. In order to extend the variety of ions more, metal viper or spatter system has also been installed to 10GHz NEOMAFIOS with minimum modifications and ion beams of Li and Mg also have been successfully obtained.

INTRODUCTION

The upgrade program of the AVF cyclotron is in progress since 2004 at the cyclotron facility of the RCNP, Osaka University [1], and it is the one of the issues to increase beam intensity and to extend the variety of ions, especially for highly charged heavy ions which can be accelerated by AVF cyclotron at RCNP. So an 18 GHz superconducting ECR ion source has been installed and the beam development has been performed since 2006. For the old NEOMAFIOS, the new micro oven system has been also developed to extend the beam variety especially for metal like Li and Mg.

HIGHLY CHARGED XENON BY SCECR

The production development of several ions like B, O, N, Ar and Kr has been already performed and delivered to user's experiments [2]. During the development many issues are introduced. The shape and material of bias probe [3,4,5] at the upper stream end of plasma chamber have been changed from rod to disk and from stainless steel to aluminum, respectively. The material of plasma electrode has also changed from stainless steel to aluminum. The cylindrical aluminum liner [6] is already installed inside the plasma chamber, so then now plasma is surrounded by aluminum which easily emits secondary electrons [5] more than the case of stainless steel. The plasma electrode position [4], bias probe position [3,4] and detail mirror flied are also optimized. Then the ion currents are intensified successfully [2]. For the next step, the beam test for highly charged Xe has been performed.

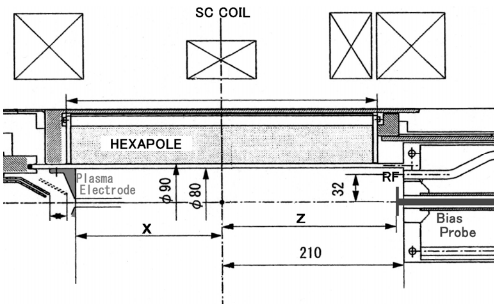

Figure 1: Schematic view of plasma chamber: "x" shows the distance between the center of center coil [2] and upper stream end of electrode. "z" shows the distance between the center of center coil and lower stream end of bias disk.

Optimization of Plasma Electrode and Bias Disk

For obtaining highly charged Xe with several μA, two sets of plasma electrode and bias disk are tested. First set (set A) has flat shaped plasma electrode (Fig.2-a-1) and bias disk with large diameter of ϕ50mm (Fig.2-a-2). Another set (set B) has taper shaped plasma electrode (Fig.2-b-1) and bias disk of ϕ30mm (Fig.2.b-2). Intensities of ^{40}Ar and ^{136}Xe ion for each case of set A and B with several plasma electrode position conditions are shown in Table 1. With set A, it is hard to obtain the highly charged Xe, because of the hardness to reduce the Xe gas pressure for increasing the highly charged ion because when the gas pressure is reduced, reflected power of RF increases and suddenly gets unstable with plasma. And $^{136}Xe^{32+}$ beam of 4.2euA is obtained successfully without such a reflected power problem by set B with the plasma electrode position of 170 mm. This position is 10 mm upper in comparison with optimum position for Ar beam. This effect of plasma electrode shape and bias disk size is not so large for lower charged Xe^{28+}. In fact, the intense beam current of Xe charged lower than 28+ has

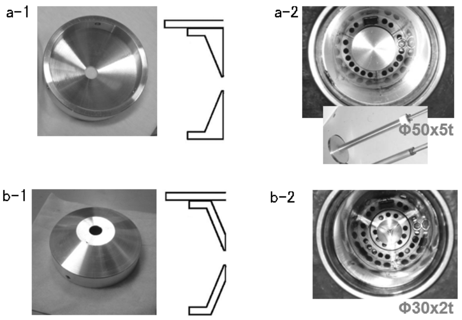

Figure 2: Plasma electrodes: a-1) shape of plasma chamber side is flat, b-1) tapered with 66 degrees. Bias disk at the upper stream end of plasma chamber: a-2) size of ϕ50mm in diameter, b-2) ϕ30mm.

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Table 1: Intensities of ^{40}Ar and ^{136}Xe for each case of A and B with several electrode position conditions. The "electrode position" is the distance between the center of center coil and upper stream end of electrode as shown in Fig. 1 by "x". The other parameters like mirror field strength, bias disk position, its biased voltage and gas flow were optimized to maximize the current for each ion and each position of plasma electrode

set	Ion(RF power)	x=180	x=170	x=160
A	Ar^{11+}(500W)	188eμA	115eμA	
	Xe^{32+} (770W)		1eμA	
	Xe^{28}+ (770W)	15eμA		
	Xe^{24}+ (580W)	72eμA	55eμA	
	Xe^{22}+ (580W)	71eμA	60eμA	
B	Ar^{11+}(500W)	150eμA	140eμA	130eμA
	Xe^{32+} (770W)		4.2eμA	3.8eμA
	Xe^{31+} (770W)	3.5eμA	6.0eμA	
	Xe^{28+} (770W)	15eμA		

been obtained with set A. On the other hand, electrode position "x" dependence for Ar gets small with the case of set B and this might be caused by the reduction of RF standing wave effect inside plasma chamber.

Bias Disk Position Dependence

To see the effect of RF standing wave inside the plasma chamber for each case of set A and B, the bias disk position dependence of ^{40}Ar^{11+} intensity has been measured. The measurement has been performed by changing only bias probe position and the other parameters like mirror field, gas pressure, bias voltage, etc. are fixed to optimum values when the bias disk is on the optimum position. The plasma electrode position was x=180mm for each case. The measurement results are as shown in Fig. 3. Large position dependence has been seen only for the case of set A and this also might be the effects of RF standing wave which is same as plasma electrode position dependence in table I. In Fig. 3-a), there are two large peak of z~185.9mm and z~194.2mm and their distance is corresponding to the half wave length of 8.33mm of 18GHz RF. This large position dependence is also seen in the case of Xe24+ with set A as shown in Fig. 3-c).

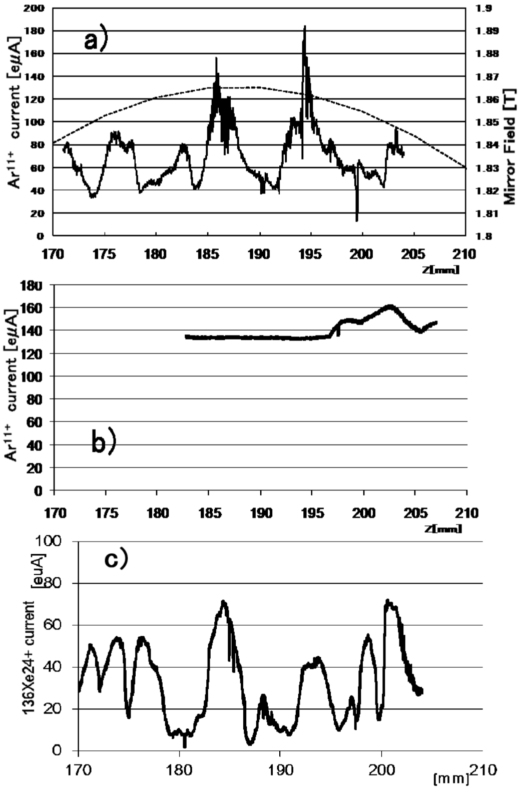

Figure 3: Bias disk position dependence of Ar^{11+} current: a): result for the case of set A. b): for B. Typical mirror field in this region is also shown in upper figure a). c): same result for ^{136}Xe^{24+} with set A.

DEVELOPMENT OF MICRO OVEN

NEOMAFIOS [7] is the 10 GHz ECR ion source for light and medium mass ions. Li ion, one of those ions, was previously produced by a LiF rod sputtering method with He support gas and more intense ion beam was needed for some experiments. For that purpose, a micro oven system has been developed with referring to DECRIS-14-2, Dubna [8].

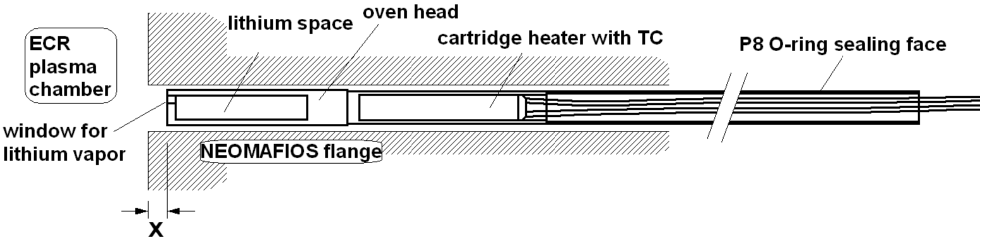

Figure 4: The micro oven system: Li or Mg metal is installed inside the oven head. Oven head is heated from back and metal vapour goes through window to plasma chamber. Heater power and oven position are controlled and the oven temperature is stabilized with the PID method.

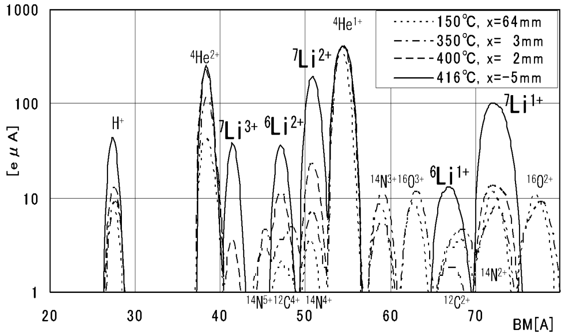

Figure 5: Li ion charge distribution spectrum. The extraction voltage is 15 kV. Support gas is ^{4}He. The x values correspond to oven position shown as x in Fig. 4.

Li Beam by Micro Oven

The detail of the Li oven is shown in Fig. 4. The micro oven system is designed to be less than 10mm diameter to avoid the modification of NEOMAFIOS itself. The oven evaporates Li from pure metal and the Li vapor is introduced into the ECR plasma chamber. Fig. 5 shows charge distributions of ions with several conditions of oven temperature and position. In case of 416deg.C, the maximum intensity case, we obtained about one order intense Li ions in comparison with LiF sputtering method. According to the Li vapor pressure calculation [9], higher temperature operation seems to be able to create more intense beam, but in such case like 450deg.C, the oven temperature got out of control because of positive feedback by plasma heating.

Long Term Stability

The developments has been continued to realize a long term stability of the system. A hot liner has been installed to avoid Li vapor condensation on the ECR chamber wall which is cooled by water. The instability of plasma sometimes happens due to this condensed Li. The liner is made of thin Ta plate and has cylindrical shape which radius is about 2-3 mm less than the plasma chamber radius. The Ta liner keeps high temperature for avoiding Li condensation by the thermal insulation from the chamber wall. The material of Oven Head has been changed to stainless steel from Cu as well. The prototype of Li oven was made of Cu because of its high thermal conduction for effective heating by cartridge heater placed in the back of the oven head. However such high thermal conduction leads positive feedback by plasma heating easily and the evaporation condition got out of control. The chemical problem between Cu and Li also occurred. Then the material of oven head has been changed to stainless steel. After these modifications, very stable Li ion production has been achieved. Currently about 10-30 eμA ^{7}Li^{2+} beam with about 3.5 days lifetime is produced with conditions of 400deg.C oven temperature, He support gas and ϕ2mm hole on the face of oven head. About 50-100 eμA ^{7}Li^{2+} with about 2.5 days lifetime is also produced with ϕ3mm hole.

Mg Beam by Micro Oven

The Mg beam test also has been done with this micro oven. In this case, oven heater has not been used and only oven position has been optimized. The oven head can be heated by plasma and the temperature can be controlled by its position. And then, about 35eμA ^{24}Mg5$^+$ is produced with ϕ3mm hole on oven head.

CONCLUSION

The further development of 18 GHz superconducting ECR at RCNP has been performed to meet the demand for more intense and highly charged ion beam. With the modification of plasma electrode and bias probe and optimization of operation parameter like magnetic mirror field, high intensity beam of O,N and Ar and highly charged Xe beam are obtained successfully. Especially for the ^{136}Xe^{32+}, taper shaped plasma electrode and small bias disk have taken an important role to avoid RF reflection under the condition of low pressure Xe gas for highly charged ion. On the other hand, for the lighter ion like Ar or lower charged Xe, standing wave effect is getting important and flat shaped electrode and large diameter bias disk have advantage.

For the NEOMAFIOS, the new micro oven system has been also developed to extend the beam variety especially for metal like Li and Mg and ion beams of Li and Mg also have been successfully obtained.

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