The 9th Symposium on Accelerator Science and Technology, Tsukuba, Japan 1993

Status of the RIKEN ECRIS's

T. Nakagawa, T. Kageyama, Y. Miyazawa, E. Ikezawa, T. Hemmi, M. Kase, A. Goto, M. Nagase, and Y. Yano
The Institute of Physical and Chemical Research (RIKEN)
Wako-shi, Saitama 351-01, Japan

Abstract

The recent developments of the RIKEN 10 GHz ECRIS and the 8 GHz NEOMAFIOS is described. We upgraded the performance of the 10 GHz ECRIS by modifying the first stage into the plasma cathode method. As a result, beam intensities produced not only from gaseous elements but also from solid materials are increased. Up to now, 47 kinds of ions were successfully extracted from the NEOMAFIOS. Recently Li, B and F ions are produced from solid rods of B and LiF.

I. INTRODUCTION

The RIKEN 10 GHz ECRIS has been operated since 1989 as an external ion source of the AVF cyclotron and many kinds of ions have been successfully extracted and accelerated up to now. Furthermore several developments have been done, i.e., coating method[1], biased electrode[2,3] and plasma cathode method[4].

For upgrading the RILAC performance , an 8 GHz NEOMAFIOS has been ordered to CEA/IRF(Grenoble, France) as a new ion source of it. The NEOMAFIOS was tested in 1990 and the beam service for users was started from 1991. Up to now many kinds of beams , not only gaseous elements but also metallic ions, have been extracted and accelerated stably.[5]

In this paper, we report the recent status of the RIKEN ECRIS's. In section II, the recent development of the RIKEN 10 GHz ECRIS (plasma cathode method) is presented. In section III , the status of the NEOMAFIOS are described. Especially, new ions such as Li ,B ,and F ions are extracted recently. The detail of this method is also presented in this section.

II. RIKEN 10 GHz ECRIS

In order to increase the beam intensity of highly charged ions, we used so-called plasma cathode method. The design and preliminary performance are described in ref. 4. The first stage was isolated electrically from the second stage. The accelerating electrode which has a central hole (10 mm) was placed in front of the first stage to extract the electrons from there efficiently. A negative bias voltage is supplied between the first stage and the electrode. Figure 1 shows the results for gaseous elements. Open and closed circles are the best results without and with using the plasma cathode method. The gas pressure of the second stage is almost one order of magnitude lower than that without using this method[4]. This is a great advantage to reduce the consumption of gas when using expensive gases like ^{36}Ar .

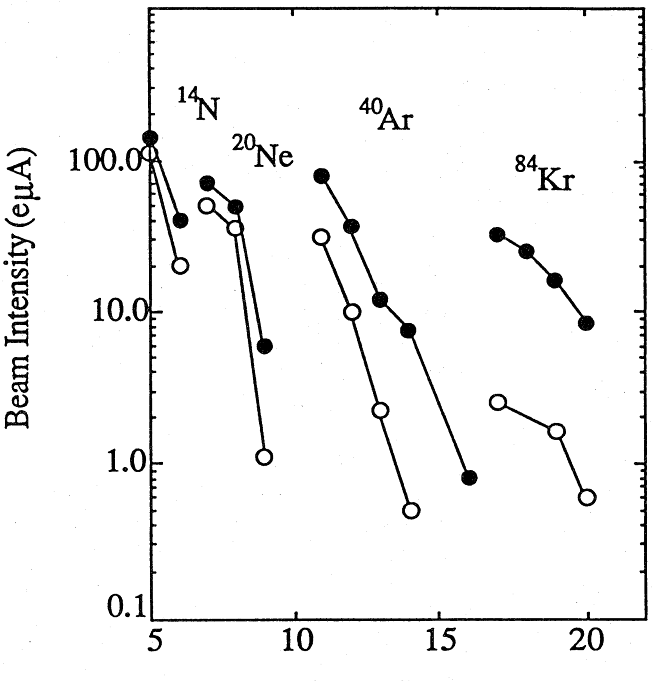

Fig.1 Charge state distributions for gaseous elements. Open and closed circles are the best results without and with using the plasma cathode method, respectively.

Recently we tried to produce metallic ions using this method. To produce Mg, Al, Ni and Zr ions, we used ceramic rods of MgO, Al_2O_3, NiO, and ZrO. These ceramic rods are inserted into the plasma region through open space between poles of the sextuple magnet in the second stage and heated to obtain the sufficient vapor pressure. Figure 2 shows the result of the metallic ions. Open and closed circles are the best results without and with using this method. The beam intensities of highly charged ions are remarkably enhanced. This is due to the increase of the electron density and electron temperature. [4]

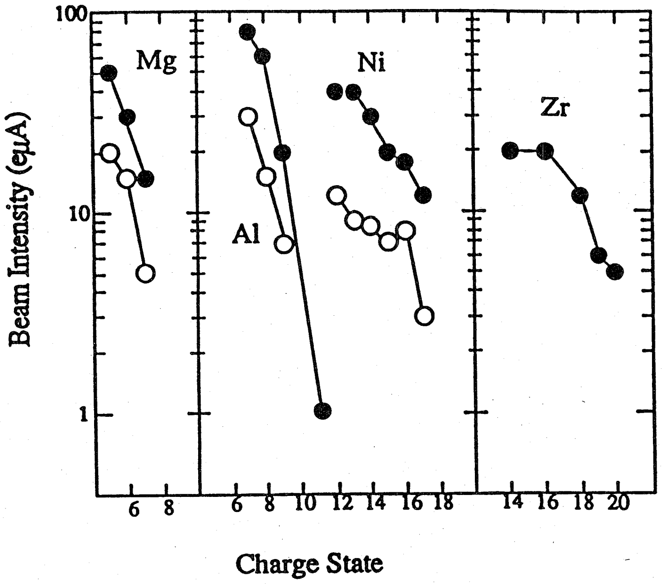

Fig.2 Charge state distributions for metallic ions. Open and closed circles are the best results without and with using the plasma cathode method, respectively.

II. 8 GHz NEOMAFIOS

The 8 GHz NEOMAFIOS is used as a new ion source of the RILAC. The results on the test bench and preliminary performance on the high voltage terminal of RILAC was already reported in ref.5.

Recently we successfully produced Li, B, and F ions using solid rods. To produce B ions, we tested the two materials: BN and B. When we used a rod of BN, the vacuum of the plasma chamber becomes worse due to outgasing from the BN and then we could not obtain enough current from the ECRIS. In order to produce F ions, we used a LiF rod . Until then, the SF_6 gas had been used to produce F ions. Figure 3 shows the beam intensity of F ions for each charge state compared to that produced from SF_6. The beam intensity of F ions produced using a Lif rod is remarkably larger than that using SF_6 gas.

The ions produced with the RIKEN NEOMAFIOS are listed in Table1. Foty-seven kinds of ions are successfully extracted from it. In this table, inverted numbers represent the ions accelerated by the RILAC and used for experiments.

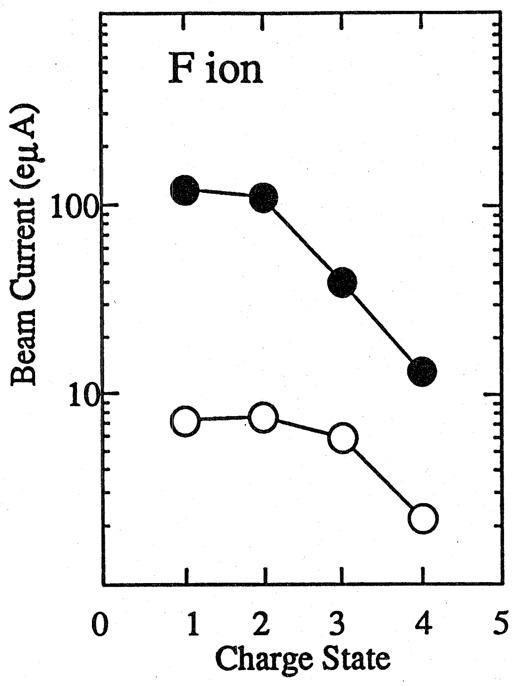

Fig.3 Charge state distributions of F ions. Open and closed circles are the best results when using SF_6 gas and a LiF rod, respectively.

III.REFERENCES

[1]T. Nakagawa: "Effect of Coating on the Plasma Chamber wall in RIKEN ECRIS," Jpn. J. Appl. Phys. 30(1991)L930

[2]T. Nakagawa and T. Kageyama,"The Effect of an Electrode in the First Stage of RIKEN ECRIS," Jpn. J. Appl. Phys. 30(1991)L1588

[3] T. Nakagawa, T. Kageyama, M. Kase, A. Goto, and Y. Yano, " Mechanism of the Increase of Highly Charged Ion Intensity by Use of an Electrode in The First-Stage Chamber of RIKEN 10 GHz ECRIS," Jpn. J. Appl. Phys. 31(1992)L1129

[4] T. Nakagawa, T. Kageyama, M. Kase, A. Goto, and Y. Yano," Plasma Cathode Method for RIKEN ECRIS," *Proc. 13th Int. Conf. Cyclotrons and their Applications*, 1992, Vancouver (World Scientific, Singapore, 1993) p365 and submitted to Jpn. J. Appl. Phys. Letter

[5]E. Ikezawa, Y. Miyazawa, M. Hemmi, M. Kase, Y. Chiba, T. Aihara, T. Ohki, and H. Hasebe," ECRIS for RIKEN Heavy Ion Linac," *Proc. 8th Symp. on Accelerator Sci. and Tech.*, 1991 Saitama, Japan (IONICS, Tokyo, 1991, p73

Table 1. Ion currents from the RIKEN NEOMAFIOS.

Ion Currents from ECR Ion Source (μ A) Jun 17 ,1993

Isotope	Gas	Charge State																							Remarks
		1 +	2 +	3 +	4 +	5 +	6 +	7 +	8 +	9 +	10 +	11 +	12 +	13 +	14 +	15 +	16 +	17 +	18 +	19 +	20 +	21 +	22 +	23 +	
^{4}He	He	500	210																						
^{12}C	CO_2,He	75	57		18	2.3																			
^{14}N	N_2,He	90	95	63	50	30	2.8																		
^{16}O	O_2	93	85	65		15	6	0.3																	
^{19}F	He	120	110	40	13	3																			LiF,4 × 4, rod
^{20}Ne	Ne,He	215	96	82	65		6.5	1.7																	
^{32}S	SF_6,He			11																					
^{40}Ar	Ar,O_2		75	55	50	[illegible]	30	24	26	10		0.7	0.1												
^{84}Kr	Kr,O_2				17.5	16			17	12	9	6.8		3.7		1.2		1		0.5					
^{129}Xe	Xe,O_2					11	11	13.5		10	6.6		3.8	3.1	2.5	2.2		1.3	1.1		0.4				
^{136}Xe	Xe,O_2									5.8			3.7	3.7	3.4	3.2	2.4		1.1		0.3				^{136}Xe (83.5%)
^{7}Li	He	106	7.2																						LiF, 4 × 4, rod
^{11}B	He	1.1	2.2	2.3	0.5																				B, ϕ 3.8
^{24}Mg	He	45				30		7.5																	MgO, ϕ 4, rod
^{27}Al	O_2		22	34	33		15	6	2																Al_2O_3, ϕ 4, rod
^{28}Si	He			15		33				1															SiO_2, ϕ 3, rod
^{40}Ca	O_2		72	70	55		36	27	27	26		5.5	1												CaO, ϕ 5.7, rod
^{48}Ti	O_2		5.2			15		14			6.5	4.4		0.3											Ti, ϕ 2, rod
^{51}V	O_2		2.5		7.5	12	12	12	10	7.5	4.8	2.4	1												V, ϕ 1, 2rods
^{52}Cr	O_2		9		27	30	33	26	15	8.3	5.8	3.6	2		0.3										Cr, ϕ 2, rod | Cr_2O_3
^{55}Mn	O_2				51	68	60	42	19	9	4	2.6	0.8												ϕ 4, Ta crucible | Mn_3O_4
^{56}Fe	He,O_2					15	15			11	8.2	4.6	3	1											Fe, ϕ 1, 2rods
^{58}Ni	He,O_2		4	4.8	5.2	8	12	14	14	11	8		1.7	0.8	0.3										Ni, ϕ 1, 2rods | NiO
^{59}Co	He		3.6	7	16	26	26	19	11	6	2.2		2	0.7	0.2										Co, ϕ 1, 2rods
^{63}Cu	O_2			9		17	19	17	15		6.5	4													ϕ 4, Ta crucible | Cu_2O
^{64}Zn	He			32		35	34	26		8.3	3.3	1.1													ϕ 4, Ta crucible | ZnO
^{74}Ge	O_2		1.8	3		4.3	5.5	6.3	6	4.6	2.6	1.3	0.5	0.3											ϕ 4, Ta crucible | GeO_2
^{89}Y	He			5.4	3.1		2.6	3	4.5	6.6	7.5		5.6		1.1										Y_2O_3, 4 × 4, rod
^{90}Zr	O_2				1		1.7	1.9	2.6	4.2	4.5	5	6.5		2.6		0.8								Zr, ϕ 2, rod
^{93}Nb	O_2			11	19	23	13	9.5	7	7	7	5	3	1.7	0.6										Nb, ϕ 3, rod
^{98}Mo	O_2				3.8	5				3.5	3			0.7											Mo, ϕ 2, rod
^{103}Rh	O_2			0.5	1.2	2.3		4.1	5.2	8.1	8.9	9.2	8.9		5.7		2.1		0.7						Rh, ϕ 1, rod
^{107}Ag	He			1.2	2.6	5.2		8.4	8.7	9	7.3	6.5	4.9	2.5	1.6	1.2	0.9	0.4							Ag, ϕ 3, rod
^{115}In	O_2			10	21	31	24	22	16	14	11	7.5	5.3	4.5	3	2	1.2	0.6	0.2						ϕ 4, Ta crucible | In_2O_3
^{120}Sn	He,O_2				3	5.2	5.7		10	7		4.2	2.7	1.8	1		0.2								ϕ 4, Ta crucible | SnO_2
^{152}Sm	O_2				0.4		0.8	1.3	1.8		4.7	5.1	6	5.8	5.3	4.9	3.6	2.4							Sm, ϕ 4, rod
^{164}Dy	He,O_2						4	5.1	5.9			6.7	4.9	2.9	2	1.8	1.5	1.1	0.7	0.3					Dy, ϕ 6.3, rod
^{165}Ho	O_2							0.7	1.2		2.5	5.3		6.4		6	5	3.9	2.6	1.6	0.6		0.2		Ho, ϕ 1, rod
^{166}Er	He,O_2							2	3	4.3		11		13		9.5	7.7	5.7	4.1	1.9					Er, ϕ 4, rod
^{180}Hf	O_2							2	2.5	3.7			7.6		6.6		4.3	3		1.3	1	0.5			Hf, ϕ 2, rod
^{181}Ta	O_2					8.5		18	19	19		14	12		8.2		5.5	5	4.3	3	2	1.1	0.6		Ta, ϕ 1, rod
^{184}W	O_2					0.9	1	1.4	1.7	2.4			4		3		1.5	0.9	0.5	0.2					W, ϕ 1, rod
^{187}Re	O_2					4.8	7	11	12	11	8.3		4.1	4.3	3.6	2.3	1.8	1	0.6	0.3					Re, ϕ 1, rod
^{193}Ir	O_2							2.9	9.2	11	8.5	6.5		5.4	4.8	3.5		1.7	0.9	0.5	0.2	0.1			Ir, 1 × 1, rod
^{197}Au	O_2						14		19	17	14		10	6		4.3	4.0	2.6	1.5	0.8	0.4	0.3			ϕ 4, Ta crucible
^{208}Pb	O_2						7.7		14	13	11	8.3			5.2		3.5		1.7	1	0.5	0.3	0.1		ϕ 4, Ta crucible | PbO
^{209}Bi	He						3.3		8.3	10	8.7	7.6	5.6		5.6		3.6	2.3	1.4	0.9	0.5	0.3	0.1		ϕ 4 ,Ta crucible | BiO_3