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PRODUCTION OF VARIOUS HEAVY IONS BY AN INVERTED SPUTTER ION SOURCE AT THE JAERI TANDEM ACCELERATOR

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ABSTRACT

Fifty elements ranging from hydrogen to bismuth were produced by utilizing an inverted sputter source installed in the JAERI negative ion source test facility, and pressed or MMP(Methyl Methacrate Polymer) binder-fabricated rods of the ion source materials. Current intensities of the most elements were measured to be tens of times higher than the Refocus UNIS sputter ion source. Lithium negative ions were accelerated to know matching property of the ion source with the accelerator. Transmission data of the Lithium and Nickel beams reconfirmed that the ion source emittance was lower than the Refocus UNIS sputter ion source.

INTRODUCTION

Since the installation date of the JAERI tandem accelerator ,June 1982 , thirty-one elements ranging hydrogen to bismuth have been successfully accelerated up to now. Negatively-charged atomic and molecular ions of these elements were obtained from a Refocus UNIS negative ion sputter source, a direct extraction duoplasmatron ion source, and a Penning ion source with radial extraction. Fourty-eight elements other than the accelerated had been extracted from the ion sources. Negative ion currents of the extracted and accelerated elements are summarized in Fig.1. Details of the ion sources and how to extract these elements were already reported in the previous papers[1,2].

As shown in Fig.1, most of the elements were availiable with the analyzed current lower than a required current intensity by experiments. In order to increase the available intensities, we decided to introduce a new inverted sputter source using a spiral ionizer made from tantalum tube[3]. It has been reported that the ion source could produce the most elements with brighter and tens of times higher current than the Refocus UNIS ion source[4]. Before the ion source would be used in the routine operation of the JAERI tandem accelerator, fifty elements from hydrogen to bismuth were tried to be produced by utilizing the ion source installed in the JAERI negative ion source test facility. In addition to the production, lithium negative ions were accelerated to know matching property of the ion source with the accelerator. In the following, the summary of the production and the acceleration of them are presented.

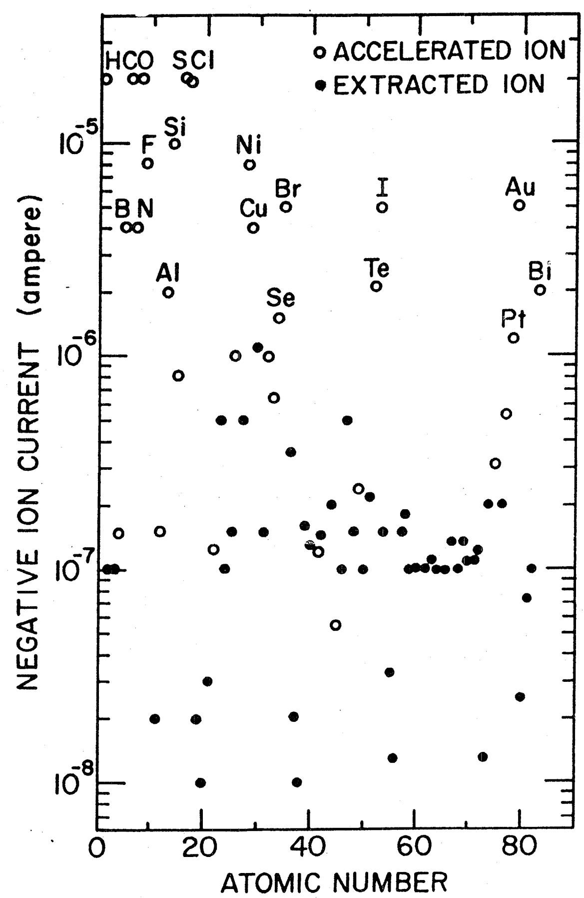

Figure 1, Negative Ion Currents of Extracted and Accelerated Elements from Hydrogen to Bismuth.

FABRICATION OF THE SPUTTERING MATERIALS

Sputtering rods of the ion source materials were fabricated by pressing powdered materials with or without impregnated binder. In the case of the rods without impregnated binder, a small hydraulic oil press was used to shape the powdered or granular materials. Some of the materials were also hand-pressed to shape in rods with MMP(Methyl Methacrate Polymer) binder, and compared with the rods without the binder. The binder used here has been successfully used for the the Refocus UNIS ion sources in JAERI tandem accelerator laboratory for this nine years. Details of the fabrication method for the sputtering rod with the binder are exactly the same for the sputtering cones[5]. We fabricated a hundred and several tens kinds of rod over the 50 elements.

NEGATIVE ION SOURCE TSET FACILITY

The neagtive ion source test facility[6] was used as a mass spectrometer to study production of the various heavy ions. Negative ion beams were extracted, focused and acclerated by an extractor and einzel lens unit made of ceramic and metal. The beam was analyzed by a double focusing 90 degree magnet with bending radius of 500mm. The beam intensities were measured by an electron-suppressed Faraday cup. Typical resolution of the mass spectrometer was observed to be about 100. The vacuum system was pumped by an Osaka 500 l/s TMP (turbomolecular pump) and a Balzers 100 l/s TMP. System pressure was in the 10^{-7} torr region.

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A typical mass spectrum of Ni in the region from mass A=1 to 100 is shown in fig.2.

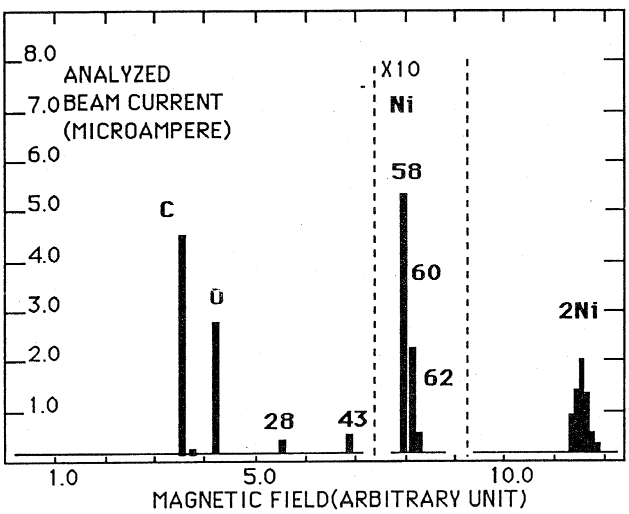

Figure 2, Typical Mass Spectrum of Nickel.

Table 1 describes summaried data of the extracted negative ion currents from a huge number of accumulated mass spectra. Fifty elements ranging from hydrogen to bismuth were extracted from the inverted sputter source, and reported in the table. As current intensities compiled in the table were obtained after a few operation of the ion source, these values should not be thought to be the maximum, should be the typical, and the easily-attainable.

Table1. Extracted Negative Ion Currents from An Inverted Sputter Source.

AtomicNumber /Element	Material Form	Binder	Analyzed Ion Beams Form	/Current (microampere)
1 H	$Sc+H_2$		H^-	23.0
	TiH_2		H^-	4.0
3 Li	Li_2O	MMP	Li^-	5.0
5 B	^{10}B (enriched)		B^-	6.2
			BO^-	14.7
6 C	C (graphite)		C^-	100.
			$2C^-$	36.
8 O	$NaHCO_3+Mo$		O^-	86.
	MgO		O^-	64.
	Sc		O^-	46.
	Zn		O^-	45.
	Zr		O^-	26.
	W		O^-	28.
	Re		O^-	62.
9 F	^{10}B		F^-	14.
	Sc		F^-	15.
	Al		F^-	11.
	TiH_2		F^-	20.
12 Mg	MgO		MgO^-	0.65
13 Al	Al (powder)		Al^-	1.0
			AlO^-	1.5
			$2Al^-$	8.5
	Al (solid)		Al^-	1.0
			$2Al^-$	8.0
14 Si	Si (powder)		Si^-	90.
			$2Si^-$	6.0
			$3Si^-$	1.0
15 P	P		P^-	21.0
			$2P^-$	1.7
16 S	NiS	MMP	S^-	22.5
20 Ca	CaO		CaO^-	0.26
21 Sc	Sc		ScH^-	5.4
			ScO^-	1.6
22 Ti	Ti		Ti^-	0.25
23 V	V		V^-	0.81
			VO^-	0.5
	VH_x		V^-	1.1
			VO^-	1.1
24 Cr	Cr	MMP	Cr^-	0.22
			CrO^-	0.4
25 Mn	Mn		MnO^-	0.5
26 Fe	Fe		Fe^-	0.9
			FeO^-	1.6
	Fe		Fe^-	1.9
			FeC^-	1.5
			FeO^-	3.0
27 Co	Co		Co^-	4.9
			CoO^-	4.0
28 Ni	Ni (solid)		$^{58}Ni^-$	6.9
			$^{60}Ni^-$	2.7
	Ni (powder)		$^{58}Ni^-$	22.1
			$^{60}Ni^-$	8.6
29 Cu	Cu		$^{63}Cu^-$	14.5
			$^{65}Cu^-$	6.6
30 Zn	Zn		$^{64}ZnO^-$	2.3
			$^{66}ZnO^-$	1.5
32 Ge	Ge		$^{70}Ge^-$	4.4
			$^{72}Ge^-$	6.4
			$^{74}Ge^-$	7.9
			$^{75}Ge^-$	1.6
35 Br	RbBr+Al		$^{79}Br^-$	23.
			$^{81}Br^-$	22.
38 Sr	Sr		SrO^-	0.04

39 Y	Y		YO^-	0.15
40 Zr	Zr		Zr^-	0.1
			ZrO^-	1.0
41 Nb	Nb	MMP	NbO^-	0.37
			Nb^-	0.8
			NbC^-	1.6
			NbO^-	3.2
42 Mo	Mo		Mo^-	0.27
			MoO^-	1.3
	$NaHCO_3$+Mo		MoO^-	0.4
			MoO_2^-	1.4
			MoO_3^-	3.9
			MoO_4^-	6.3
44 Ru	Ru		Ru^-	0.46
			RuO^-	0.3
			$2Ru^-$	0.6
			Ru_2O^-	0.5
45 Rh	Rh	MMP	Rh^-	6.5
			RhC^-	2.6
			$2Rh^-$	0.6
46 Pd	Pd		Pd^-	0.14
			PdO^-	0.4
			$2Pd^-$	0.7
			$3Pd^-$	0.2
47 Ag	Ag	MMP	Ag^-	20.7
			$2Ag^-$	1.5
			$3Ag^-$	1.3
50 Sn	Sn		Sn^-	0.4
			$2Sn^-$	2.5
			$3Sn^-$	1.4
51 Sb	Sb		Sb^-	2.0
			SbO^-	2.0
			$SbO2^-$	3.0
			$2Sb^-$	4.0
			$3Sb^-$	2.2
52 Te	ZnTe	MMP	Te^-	6.85
53 I	KI+Al		I^-	38.
55 Cs	Cs_2SO_4+Ag		Cs^-	0.2
57 La	La_2O_3		La^-	0.02
			LaO^-	0.12
			LaO_2^-	0.58
64 Gd	Gd_2O_3+Ag		GdO^-	0.2
72 Hf	Hf		HfO^-	0.15
73 Ta	Ta		Ta^-	0.11
			TaO^-	0.64
			TaO_2^-	0.17
74 W	W		W^-	1.14
			WO^-	1.84
			WO_2^-	1.77
			WO_3^-	1.38
75 Re	Re		Re^-	0.11
			ReO^-	10.8
			ReO_2^-	12.6
			ReO_3^-	5.7
			ReO_4^-	1.5
76 Os	Os		Os^-	5.7
			OsO^-	8.6
			OsO_2^-	1.1
			$2Os^-$	1.3
77 Ir	Ir		Ir^-	24.
			IrO^-	3.4
			$2Ir^-$	3.6
78 Pt	Pt	MMP	Pt^-	19.5
			$2Pt^-$	1.5
79 Au	Au		Au^-	82.
			$2Au^-$	7.5
			$3Au^-$	6.0
81 Tl	Tl_2O_3+Fe		TlO^-	1.7
83 Bi	Bi		Bi^-	0.3
			BiO^-	1.3
			BiO_2^-	1.62
	Bi_2O_3	MMP	Bi^-	0.48
			BiO^-	1.6
			BiO_2^-	5.7

ACCELERATION OF LITHIUM IONS

Lithium ion beams were accelerated to investigate optical matching properties of the ion source with the negative ion injector and tandem accelerator. In comparing with the lithium current intensity analyzed in the test facility, the intensity after the injector were measured to be about one-tenth of the intensity in the table1. The bad transmission through the injector was thought to be caused by weak focusing of the inflector magnet in the injector.

Table 2 describes the acceleration data of the lithium ions. The beam currents were measured by electron-suppressed Faraday cups distributed along the accelerator beam lines[7].

Table 2. Acceleration of lithium ion beam.

Terminal Voltage	14.88	MV
Ion Source Voltage	20.0	kV
Preacceleration Voltage	198.4	kV
Final Energy	59.7	MeV
Final Charge State	3+	
Beam Current at Injector	4.7	microamperes
Beam Current at Injection Line	0.6	microamperes
Beam Current before Foil Stripper	0.3	microamperes
Beam Current after Foil Stripper	0.7	microamperes
Beam Current after Analyzer	0.7	microamperes

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