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A SIDE EXTRACTION PIG ION SOURCE WITH PERMANENT MAGNETIC MIRROR FIELD

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Summary

The present work describes the principle, structure and experimental results of a side extraction PIG ion source with permanent magnetic mirror type field. The source is light and handy with low power consumption and high ionization efficiency. In the experiments using BF_3, N_2 and Ar, total beam current of 1-2 ma can be obtained with 50-150 watt arc power. The relative yields of $^{11}B^+$, $^{14}N^+$, $^{40}Ar^{2+}$, $^{11}B^{2+}$ and $^{14}N^{2+}$ are 50-60%, 70-80%, 20-30%, 5% and 7% that of total beam, respectively. $^{11}B^{3+}$, $^{14}N^{5+}$ and $^{40}Ar^{6+}$ are also measurable. In addition, a multicathode side extraction PIG ion source has been developed, in which a new extracting way called ACE (anode-cathode-extraction electrode) are used.

Introduction

The side extraction PIG ion source is important one of the multiply charged ion sources. However, high power consumption, big and heavy electromagnet for producing high enough magnetic field limit its application. In addition, the magnetic field distribution of this kind of ion source need improve also (1, 2, 3). In order to simplify the structure of the side extraction PIG ion source, and improve its functions so that its application can be extended, we probed into the form of the magnetic field distribution. A small sized cold cathode PIG ion source with side extraction has been developed. The magnetic mirror type field of the source is produced by SmCo permanent magnet (4, 5). Therefore the source is light and handy with low power consumption and high ionization efficiency. Single and multiply charged ions can be extracted from the source, and total beam of 1-2 ma can be obtained with 50-150 watt arc power. The source can be easily used in small accelerators and ion implantors.

Principle of the ion source

The schematic diagram of the source principle and the inhomogeneous magnetic field along the central axis of the discharge chamber are shown in Fig.1. The operation principle of the ion source is similar to that of the conventional side extraction PIG ion source, but the magnetic field form is different. Actually, the magnetic mirror field procuced in the ion source by permanent magnet, and the charged particles are compressed both in radial and axial direction, consequently the electron escape decreases and the ionization efficiency increases and the plasma produced by discharge can be compressed into the week magnetic field zone (i. e. near the anode extraction hole). Where the successive ionization and ion density are enhanced. It is thus favourable for increasing the yields of atom or multiply charged ion as well as the extracted beam current density.

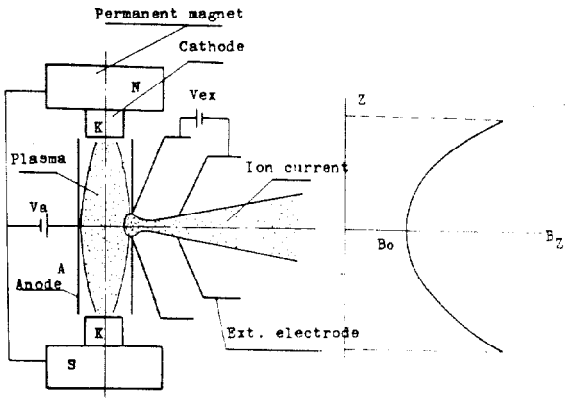

Fig. 1 Schematic diagram of ion source principle and distribution magnet field on axial

Magnetic field of the ion source

The real magnetic field distribution of the source, as shown in Fig.2, is produced by 30x30 mm SmCo permanent magnet. Fig.2 (a) shows the field measured on the axis(r=0) and at the wall of arc chamber(r=4 mm), respectively. In which Bo, Bm and Bc are the axial magnetic field strength at the center, two ends of discharge chamber and near by cathode surfaces, respectively. Fig.2 (b) shows field measured along the radial of cathode surface. The results of our experiment showed that this field distribution is better than in Fig.1.

Structure of the ion source

The structure of the ion source is shown in Fig.3. The contour of the source is 130x80x60 mm. The discharge chamber is a graphite cylinder of 8x30 mm with a Φ2-3 mm extraction hole. The cathodes are LaB_6 disks of Φ8 mm. The experiments show that LaB_6 cathodes have good electron emission, anti-poisoning and anti-sputtering, so it is one of the best cathode materials for this source.

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The Pierce extraction system is adopted and two ways of extraction for the source are tested. One of them is normal as shown in Fig.1, the other one is called ACE (anode-cathode-extraction electrode) extraction which is shown in Fig.4. With ACE extraction one can simplify the source structure and adopt multi-cathode in the source. The experimental results indicated that the effects of the two extractions are similar (6).

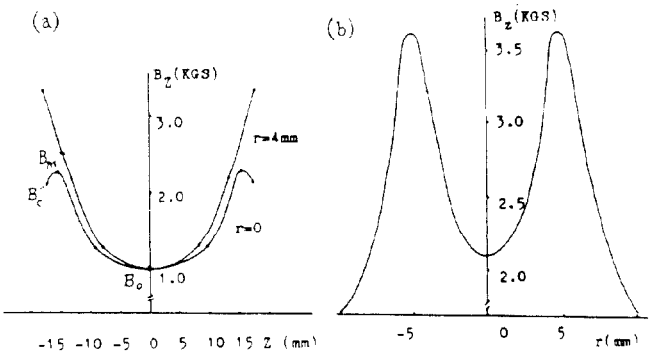

Fig. 2 Real magnetic field distribution, (a) measured field on the axis(r=0) and at the wall of arc chamber (r=4 mm), (b) measured field along the radius of cathode surface

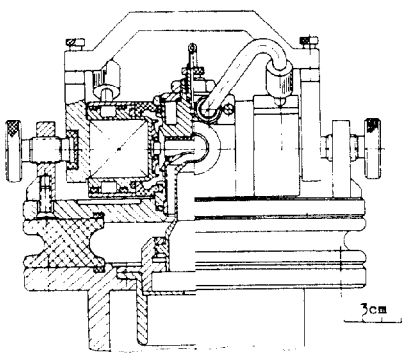

Fig. 3 Construction of the ion source

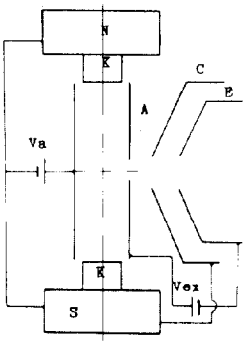

Fig. 4 Schematic diagram of ACE extraction way

The experimental results

Using hydrogen, helium, nitrogen, borontrifluoride and argon as discharge gas, we have got some typical results shown as table (1), (2) and Fig.5,6 in our test bench. In table 3 some results are given from the source in a 200Kv ion implantor. Normally beam current density of this type of source is about 100-300 ma/cm^2. A_{arc}, the energy spread of the ion beam from this source is about 50ev. The cathode lifetime is more than 50 hours except using BF_3 as discharge gas. The results of I^{n+} mentioned above have been got in our test bench at the extraction voltage Vex=20-25KV and the system transmission efficiency of about 40-50%. Using similar source structure J.Yu (7) has got better results (table 4) in the laboratory of IKF, F.R. Germany. The main differences in the experimental conditions are such that he used a test bench with high transmission efficiency till 80% and 30KV extraction voltage.

Table I Ion current vs. discharge performance V_{ex}=2.5KV

Gas	Ion	Va	Ia	Pa	It	I^{n+} μA					
		Kv	mA	w	mm	1	2	3	4	5	6
H_2	$^1H^+$	0.3	80	24	1.2	125					
		0.3	200	60	1.5	250					
H_e	$^4H_e^{n+}$	0.4	70	28	1.0	400	5				
		1.5	80	120	1.15	500	30				
N_2	$^{14}N^{n+}$	0.5	80	40	1.0	210	12	0.15	0.3		
		0.4	250	100	1.5	450	35	0.5	1.1	0.01	
BF_3	$^{11}B^{n+}$	1.1	100	110	0.6	140	4				
		0.6	250	150	1.2	300	12	1.5			
A_r	$^{40}A_r^{n+}$	1.5	50	75	0.9	250	32	1.5	1.1	0.1	
		0.5	200	100	1.3	300	120	10	2.5	0.3	0.015

Table II The percentage of single and two charged ion

Gas	H_2	He	N_2		BF_3		A_r
Ion	$^1H^+$	$^4He^{2+}$	$^{14}N^+$	$^{14}N^{2+}$	$^{11}B^+$	$^{11}B^{2+}$	$^{40}Ar^{2+}$
Ion peccentage (%)	85	4	80	7	60	5	30

Table III Target ion current of implantor with the ion source

Gas	Ion	Va	Ia	Pa	Vex	I^{n+} μA		
		Kv	mA	W	Kv	1	2	3
BF_3	$^{11}B^{n+}$	0.66	200	132	20	310		
N_2	$^{14}N^{n+}$	0.5	85	42.5	20	300	13	0.1

Table IV (7) Vex = 30KV

Gas	Ion	Va	Ia	Pa	I^{n+} μA				
		Kv	mA	W	1	2	3	4	5
BF_3	$^{11}B^{n+}$	0.9	100	90	275	8	0.15		
		0.45	250	112	505	13.5	0.15		
Ar	$^{40}Ar^{n+}$	0.55	100	55	700	210	15	1.5	0.10
		0.55	180	99	620	280	29	2.8	0.19
N_2	$^{14}N^{n+}$	200	280	56	1000	40	0.5		

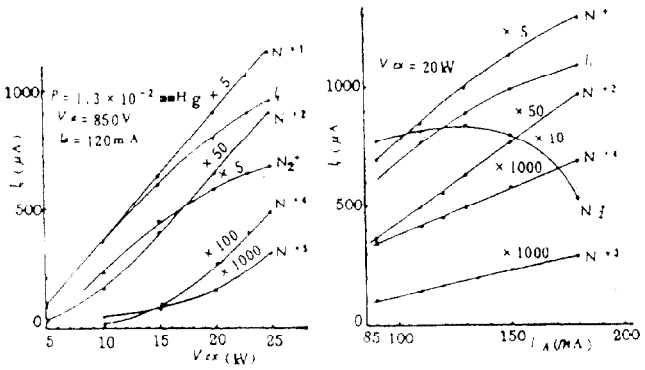

Fig.5 Total beam current I_t and different charged ion current I^{n+} Vs. extraction voltage V_{ex} and arc current I_a

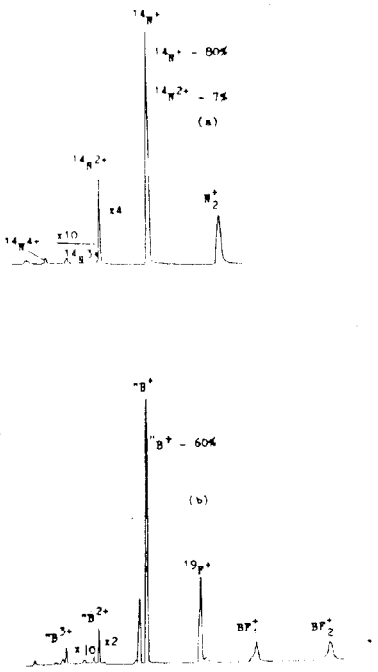

Fig.6 Mass spectra of N_2(a) and BF_3(b)

The experimental results indicate that the source has higher ionization and extraction efficiency. The percentage of atom ions or multiply charged ions in the source is much higher than that in the other ion sources with low power consumption. The beam current density in the source is higher too than that in conventional side extraction PIG ion source (8).

In the experiments we found out that the magnetic field distribution near by cathode surface play a major role for the discharge state, but the magnetic field strength B_o in the middle of discharge chamber is not sensitivity for discharge state. With B_o from 800 to 1500 Gauss the source can work stably. Some discussions of the experimental results of the source are given in detail in references (9,10).

Now, we are studying a side extraction PIG ion source with multi-cathode. The results of preliminary experiments are satisfactory. In this source cathodes can be easily changed without destroying the vacuum of discharge chamber. It will be favourable for increasing lifetime of the source.

Conclusions

We have been studying side extraction PIG ion source with permanent magnet for a few years. The experiments show that the influence of the magnetic field distribution is very important in the source operation. One should pay attention to magnetic field form nearby cathode surface especially, and research and optimization on the magnetic field of the source may be a effective way for improving the performance of the side extraction PIG ion source. The side extraction PIG ion source with permanent magnet can be used in many places because it is light and handy with low power consumption and high ionization efficiency. Further improvement is still on the way.

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