AN INTENSE ALPHA ION SOURCE FOR INRS CYCLOTRON

Lin-xing Chen and Mao-bei Chen
Institute of Nuclear Research, Shanghai, China

Abstract

An intense PIG alpha source for INRS has been developed with low arc power and low gas flow. Generally, the alpha yield of the new source is twice as much as the old one. The structure and character of the source and its experimental results both on the bench and cyclotron will be described in this paper.

Introduction

Owing to the space limitation of the new central region in remodelling of the INRS cyclotron, the height of the original source chamber had to be shortened from 105 mm to 55 mm. As a result, the yield of alpha beam was so dropped that it could not meet the need for the preparation of isotope. A new alpha source was then developed under such height limitation. We designed and manufactured a new sturcture of the arc chamber as well as anticathode assembly, which has changed operating mechanism of the source and increased the alpha beam yield. To compare new source with old one on the bench, a set of new yield measuring device with 180^{o} mass spectrograph type has been assembled, which has improved the resolution and flexibility of measuring ion yield with various specific charge.

New structure of the arc chamber and anticathode

The structure of both new and old source chamber are shown in Fig.1. Arc chamber is made of water-cooled copper. The filament and the anticathode are separately inserted through and supported by two copper pipe, the filament has a shape of letter U. The new source (II) is different from the old one (I) in following aspects: (a) The original water-cooled tungsten anticathode is changed into a thermally and electrially insulated tantalum one, which is embeded into a boron-nitride sleeve, through which the whole anticathode assembly is supported by a water-cooled pipe. Thus the new anticathode now becomes an electron emitter rather than only a reflector, and the NeTi value is then increased, of which Ne is electron density and Ti is ion confinement time within plasma[1]. The anticathode, 9mm in diameter and 11 mm in height, can be similarly replaced under vacuum condition, as the replacement of the filament. (b) The original arched inner wall of the source exit slit is flatted and the geometric axis of the arc chamber is backward offset about 0.5 mm from the central column of discharge plasma, thus the exit slit is colser to the central column of discharge plasma for about 1 mm to minimize the recombination of alpha particle on its drained way[2]. (c) The cross section of the arc chamber is changed into a round with 6 mm in diameter from original square with 5×8 mm^2, and the height of the arc chamber is lengthened to 60 mm from 55 mm[3], thus the length-diameter ratio of arc chamber is increased as possibly to facilitate to increase the alpha yield. (d) Gas flow inlet on the chamber wall is reduced to single hole near filament from original three holes[4].

Yield measuring device

To select a better chamber structure and determine the optimum operating parameters, following trials were tested on the bench during the development process of ion source: (a) arc chamber material: water-cooled copper and non-cooled graphite. (b) a varieth of auxiliary gas: H_2, C_2, N_2, Ar; (c) anticathode material: Mo, W, Ta; (d) different arc chamber diameter: 5mm, 6mm; (e) gas flow inlet: single hole, two or three holes.

Tests were proceeded on an ion source bench with a new designed yield-measuring device which is equivalent to a 180^{o} mass spectrometer as shown schematically in Fig.2. The pole diameter is 30 cm and maximum magnetic

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field is 8 kG. Particles emitted from source 1 pass through puller 2 and enter a small Dee structure 3. After drifting semi-circle in a uniform field, particles eject from a movable slit 4 of 1.5X28 mm^2 and received by a Faraday cup 5 with shield box 6. Yield is measured by either microamperemeter with range switch or recorded on a X-Y recorder. Fig.3 is a typical He ion spectra.

In order to receive ions with different specific charge, beam receiving Faraday cup 5 can radially move through a reversal motor and a gear reducer. The slit 4, which is in Dee voltage, can synchronously move with the cup 5 which is in ground potential, through a specially designed boron-nitride insulator 7 (Fig.4).

At the very beginning, the BN insulator was located on the medium plane of the bench chamber and its insulation was rapidly deteriorated by ions and other stray particles formed in discharge of bench chamber which axially and radially hit the insulator in a crossing electric and magnetic field. After testing for many times, the insulator is located beyond the dee upper or lower surface by taking shape of an arch bridge to alleviate ion hit. Furthermore, the insulator edges in two sides were cut by drilling three holes to create three un-contaminative regions on the insulator surface for securing its insulation.

Results

1. Testing results on the bench are shown in table I. The yield of new source is twice as much as the old one. The differential beam peak on the Faraday cup reached 360µA with source exit slit of 1.5X5 mm^2.

2. Results on the cyclotron are shown in table II. The alpha beam at the extraction radius prior to deflector reached 27X5µA (ie,repetition frequency 2000/s,pulse width 1ms),which was twice as much as old source and coincide with result on the bench.

3. In addition, the power and gas consume of the new source are obviously reduced. Especially the new alpha source is operating under the condition with higher arc voltage(300-400 V) and low arc current (~2A), thus the filament current often is below 100A. It is of significant difference from the old source, which operated with 200 V arc voltage and 7-8 A arc current.

References

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Table I. Bench test results of ion sources with different structure

source number	arc dimension (mm)	anti-cathode		alpha beam				proton beam			
				discharge parameters			yield (µA)	discharge parameters			yield (mA)
		material	cooling manner	U_A (V)	I_A (A)	g_{He} (cc/min)		U_A (V)	I_A (A)	g_{H_2} (cc/min)	
I	5X8X55	W	water cooling	200	4-7	5	120-180	160	3	5	3
II	Ø6X60	Ta	BN insulating	350	2	4	300-360	160	3	5	4
III	Ø5X60	Ta	BN insulating	350	2	4	310-330	160	3	4	2

Table II. Cyclotron test results of the source I and II

source number	operation parameters			arc power (kW)	arc exit slit (width×height) (mm^2)	internal alpha beam (μA)
	U_A (V)	I_A (A)	g_{He} (cc/min)			
I	200	7.5	10	1.5	2.5×5	65
II	300	2.3	3.1	0.7	2.0×5	135

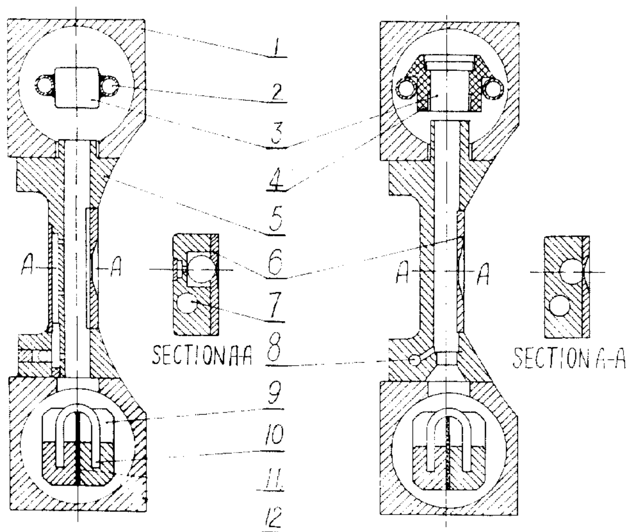

Fig.1 The structure of both new and old source chamber

1. Upper supported pipe; 2. Water-cooling tube; 3. Anti-cathode ; 4. BN sleeve ; 5. Arc chamber; 6. Source slit plate ; 7. Cooling hole ;8. Gas inlet;9. Filament support ; 10. Filament ; 11. Insulator ; 12. Lower supported pipe.

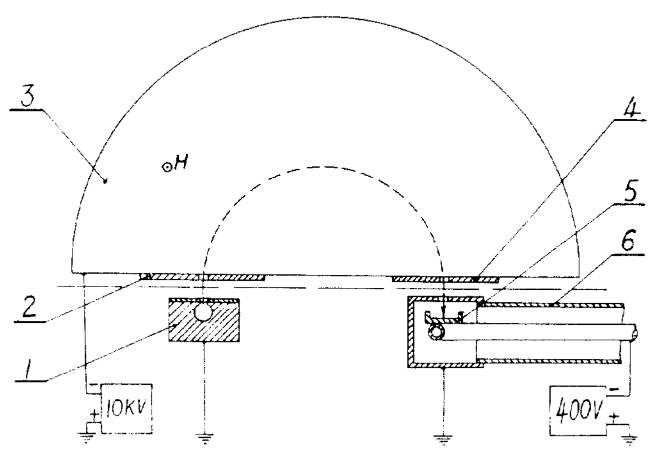

Fig.2 The schematic diagram of the yield measuring device

1. Ion source ; 2. Puller ; 3. Small Dee ; 4. Extraction slit ; 5. Faraday cup ; 6. Shield box .

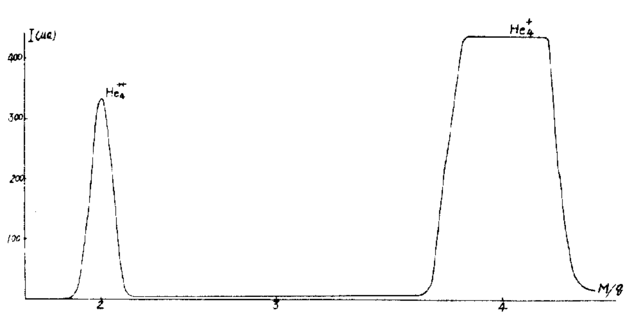

Fig.3 A typical He ion spectra obtained by new measuring device

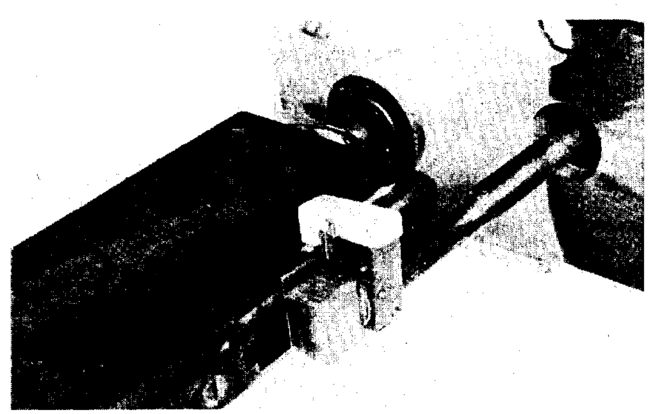

Fig.4 A photo graph of the special BN insulator