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Introduction

A rapid surface ionization ion source of a pipe-type /1/ has been developed to separate small amounts of radioactive isotopes. Its separation efficiency is near 100% for materials with the first ionization potential of $V_i \leq 5$ eV and decreases to 1% for $V_i = 7$ eV. This source can be used for about 50 elements including the actinides /2/.

In this work a further improvement of this device is given enabling simultaneously surface ionization and ionization by using the hollow cathode plasma (see e.g. /3/). By this way one can obtain the ions practically of all elements even that of the high-melting ones up to niobium.

Ion Source Construction

Figure 1 shows schematically 3 construction variants of the source. All three types have a tungsten or tantalum hollow cathode (4) emitting electrons to develop a gas discharge between the cathode and anode (1). To obtain thermoelectrons and surface ionization the hollow cathode is heated by electron impact from the filaments (3) and (6) (extra heater). The filaments are one turn, tungsten made and 1 mm across. The anode is an isolated tungsten tube (I). In the variant (a) the support gas is fed into the source via this anode tube. In the variants (b) and (c) the solid charge materials may be introduced through the anode tube by means of a small charge ampule (5) fastened to a movable rood (8). The temperature gradient (see Fig.2) along the tube allows to choose the evaporation speed. The outlet diameter has been varied from 0.1 to 1.0 mm. The source operates without external magnetic field. The typical operating conditions for the ion source are given in Table I.

Table I

Source type	Discharge		Electron impact		Filament (3)		Filament (6)	
	I/A	U/V	I/A	U/V	I/A	U/V	I/A	U/V
a	$\leq$ 3	20-40	~ 0.3	400	45	6	-	-
b	$\leq$ 5	30-80	~ 1.0	450	45	6	35	4
c	$\leq$ 5	30-100	~ 0.7	350	45	12	35	8

Results and Discussion

It has been shown that stable discharge conditions are easily obtained by feed rates of ≥ 1 cm^3/h. Figure 3 shows the total Xe ion current as a function of the discharge current for an exit hole 0.3 mm across. The efficiency equals roughly to 13% if the ion current density exceeds 1.1 a/cm^2 . The amount of double charged Xe ions is about 20% of the total ion current. We have been guided by the following ideas in constructing the variants (b) and (c): The ionization probability (see e.x. D.Bohm) is

$$P_i = 1 - exp\ (- < \sigma_i\ v_e > n_e \bar{\ell} / v_0) ,$$

$< \sigma_i\ v_e >$ is the product of ionization cross-section and electron velocity averaged by the electron velocity spectrum; n_e is the electron density; v_0 is the neutral velocity; $\bar{\ell}$ is the mean range of the neutrals (Ω is the internal discharge volume, S is the surface bordering this volume). In our case $\bar{\ell} = 4\Omega / S$ equals the hollow cathode diamater D.

For $P_i = 0.6$ one gets:

$$< \sigma_i\ v_e > n_e D / v_0 = 1 .$$

Using $n_e \sim n_i$ which denotes the quasineutrality and stationarity for the plasma one can obtain the following equation:

$$j_i MD \simeq 2ek \sqrt{T_e T_0} / < \sigma_i\ v_e > \sim const ,$$

where j_i is the ion current density extracted from the plasma; M is the ion mass; T_e and T_0 are the electron and neutral temperatures; e is the electron charge and k is the Boltzmann constant.

This equation describes qualitatively the relation between the efficiency, the extracted ion current, and the dimensions of the discharge region. It means that for a high efficiency the low current density of the usual Laboratory isotope separations has to be compensated by increasing the dimensions of the discharge chamber. For this purpose the diameter of the discharge chamber has been enlarged by a factor of 3 and 16 for the variants (b) and (c), respectively. However, the experiments did not prove the expected efficiency increas. We suppose it is concerned with a number of factors as the presence of a positive anode fall, possible cathode overheating, and mainly with a probably resonance charge exchange. The experiments are provided to optimize the discharge parameters and to select the appropriate geometry and surface area of the hollow cathode (Sc) as well as anode (S_a) under the condition to avoid the positive anode fall which reduces the cathode fall. To ensure this one should follow e.g: $S_a / S_c \geq 4 (m / M)^{1/2}$

m is the electron mass.

It is also provided to examine the resonance charge exchange process in the outlet region which has a cross-section of about the gas kinetic value. In this case the efficiency of the ion source may be decreased. The preliminary results with the type (b) ion source suggest that the efficiency for radioactive zirconium is near 1% and 5 times smaller for niobium.

Conclusion

The described ion source, at least the variant (a), can be used in nuclear physics experiments with on-line or off-line facilities. Particularly, in the last case the source is very convenient for a long and leak-proof operation at high temperatures (~2500 °C). This allows one to irradiate the targets immediately in the source and extract the radioactive nuclei by thermodiffusion [4]. The recoil nuclei from the heavy ion reactions may be stopped on the heated hollow cathode surface.

Investigating the short-lived isotopes one can sufficiently decrease the discharge chamber volume but this is connected with decreasing of the efficiency. For a type (a) source one can get, e.g. a hold-up time of the milliseconds order. The selectivity of the source operating with a discharge or surface ionization simplifies the mass spectra identification.

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References

1. G.Beyer, E.Herrmann, A.Piotrowski, V.I.Raiko, H.Tyrroff. Nucl.Instr.& Meth., 96/3, 437 (1971).
2. G.Beyer, E.Herrmann, F.Molnar, V.I.Raiko, H.Tyrroff. JINR Communication,E13-6671, Dubna, 1972.
3. G.Sidenius. Proceedings of the International Conference on Electromagnetic Isotope Separations, Marburg, 1970.
4. R.Arlt, V.A.Bystrov, W.Habenicht, E.Herrmann, V.I.Raiko, H.Strussny, H.Tyrroff. JINR Communication, E13-6224, Dubna, 1972.

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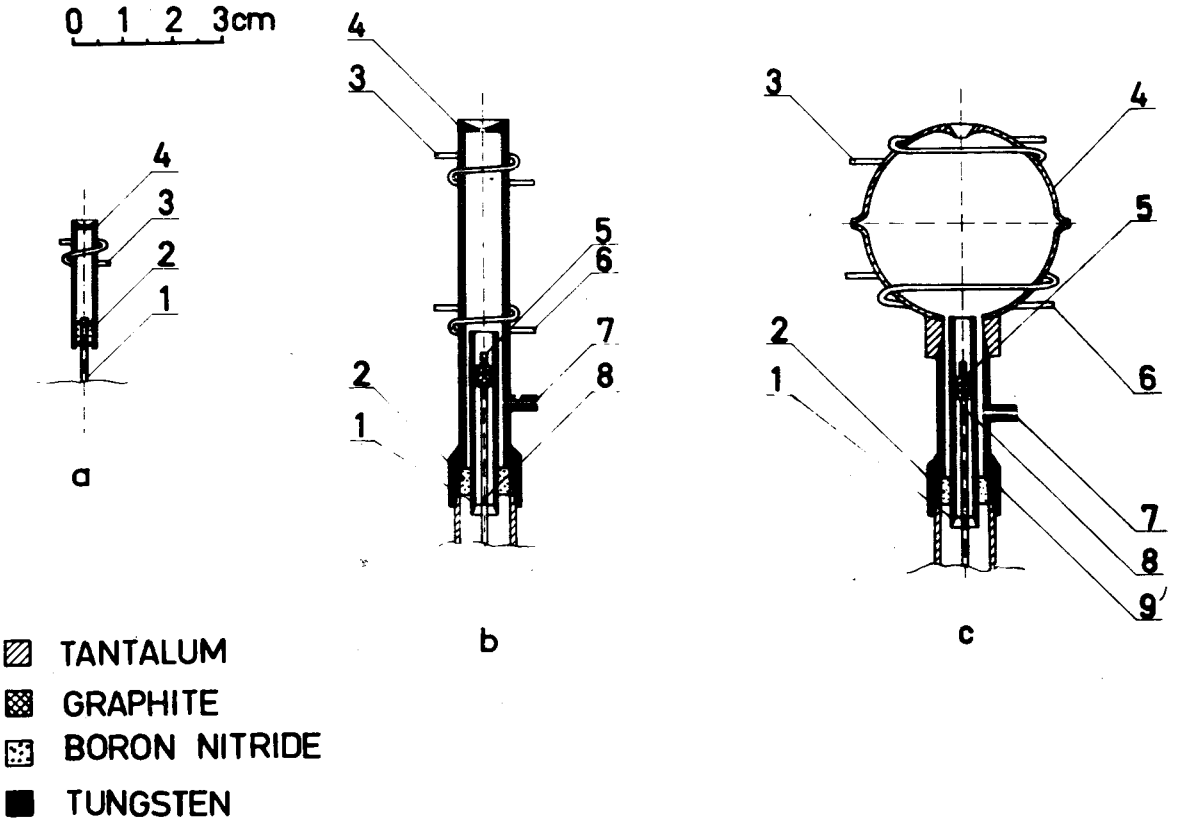

Fig.1. Variants of the ion source with surface ionization and hollow cathode discharge. (1) is the anode, (2) - anode isolator, (3) - filament, (4) - hollow cathod, (5) - sample holder, (6) - extra filament, (7) - gas lead in, (8) - movable rood, (9) - connection pipe.

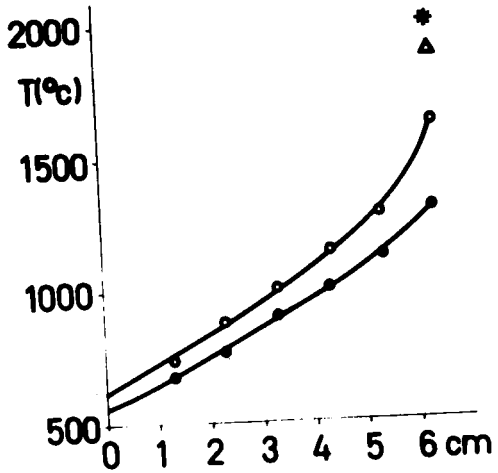

Fig.2. Temperature distributions along the anode of the type (b) source: ● -without discharge; O - with discharge current = IA; voltage 40 V; Δ– I_d=2A, U_d=50 V, ✱ – I_d = 3A, U_d=60 V. Electron impact power all the cases P = 370 W.

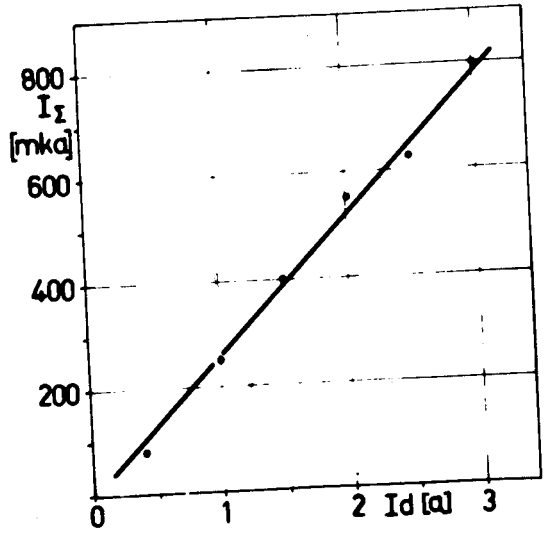

Fig.3. Total Xe ion current versus discharge current (type (a) of the source). Outlet diameter δ = 0.3 mm; Xe flow into the ion source κ = 5 cm^3 /h; Discharge voltage 20-30 V; Electron impact power 120 W.