ION SOURCE OF REACTIVE GASES WITH DECREASED NEUTRAL GAS INLEAKAGE

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Ion source with an original system of ions extraction from the discharge chamber, allowing more then on order of magnitude reducing of neutral gas incoming to the chamber of ion beam acceleration and use is described. The parameters of a received beam of nitrogen ions and possible variants of the source application have been given.
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One of problems of obtaining and using high current beams of charged particles extracted from the discharge plasma is the large amount of neutral gas incoming from the gas discharge chamber into space of particle acceleration and application.

To decrease neutral gas incoming from the discharge chamber it is possible to use difference in the behavior of neutral and charged particles in the electrical field. The electrical field influences on the charged particles movement only.

Fig.1a shows the typical scheme of ion extraction from the discharge region through the hole in the cathode on an example of the hollow cathode discharge. The plasma area is shaded, by the light interval between the plasma and chamber wall is schematically shown the cathode fall layer, which electrical field accelerates ions towards the wall.

Fig.1b shows the offered scheme of ion extraction from the discharge chamber.

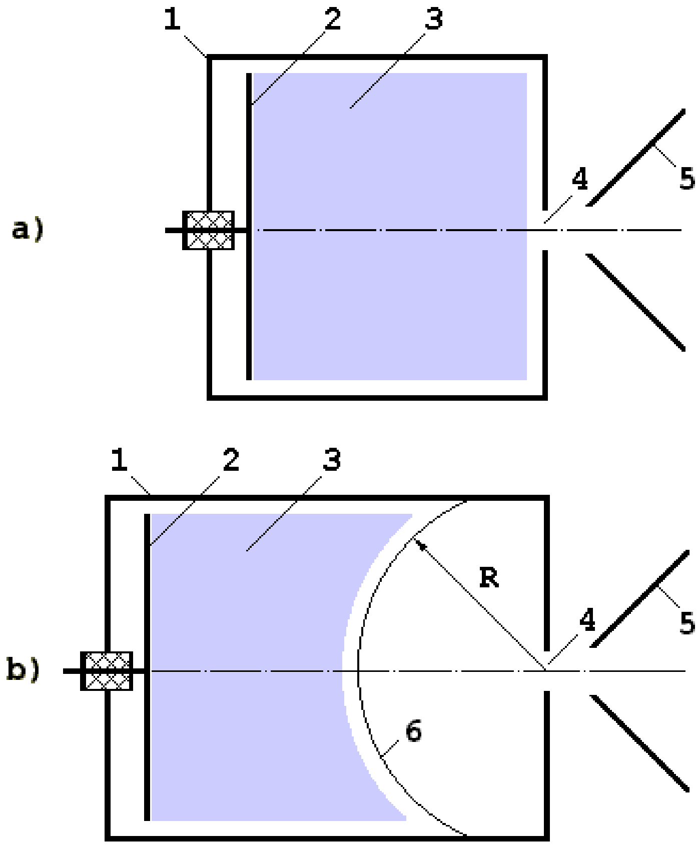

Fig. 1: 1 – cathode; 2 – anode; 3 – generated plasma; 4 – hole, through which ions and neutral gas incoming into the area of acceleration and application of ions; 5 – accelerating electrode; 6 – sphere segment shaped grid

The unique difference from the scheme, shown in Fig.1a, is the presence of the grid of the sphere segment shape between the area occupied by the plasma and the output hole located so that the sphere center is on the symmetrical axis of the system in plane of output hole.

In this scheme ions in the boundary between the plasma and the grid are accelerated by the layer potential difference in the direction to the hole. In the ideal case of all ions, accelerated by the layer potential difference, passing through the output hole, the incoming decrease equals to the plasma contact area with the grid and output hole area ratio. Really such an ideal picture may occur only in case of small ion beam currents, when the ion beam volume charge cannot appreciably influence on their trajectories. The ion beam volume charge may result in beam swelling and loosing part of ion beam on the face wall near the output hole. As a rule, when the ion beam passes the drift space free from external electrical fields its volume charge compensation by electrons occurs, therefore only the experiment may answer, what ion beam part does not pass through the output hole due to the volume charge or any other cause.

As possible variants of plasma generation in a discharge chamber next methods, described in literature, have been tested:

– Discharge chamber with a cold hollow cathode and extraction system with one grid without and with the magnetic multipole system of constant polarity [1,2];
– Plasma generation by Penning discharge [3].

The plasma generation method should satisfy to the following requirements: plasma generation of given density with the minimal gas incoming into the discharge chamber; simplicity of realization; possibility of ion reactive gas generation.

Results of researches in case of Penning discharge are given below. This variant of plasma generation turned out the best one. Gas incoming here is rather less than in case of discharge with the hollow cathode and there are no problems with discharge ignition. The ion source scheme is presented in Figure 2. Electrodes 1, 2 (stainless still wire grid) and 4 are the cathodes and electrode 3 is the discharge anode. The potential applied to the electrode 4 differed from the potential of electrodes 1 and 2 allows to improve to some extent the accelerated ion current homogeneity at the collector.

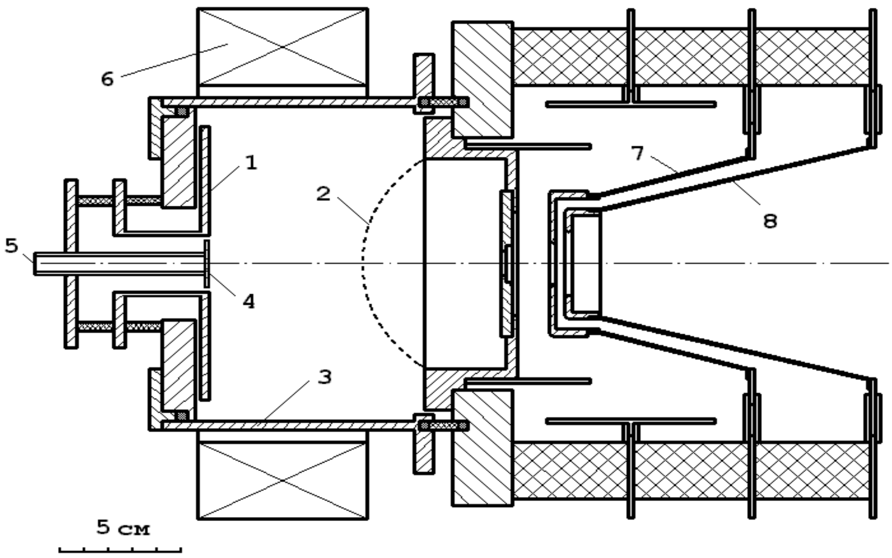

Fig.2. Penning's ion source scheme: 1, 2 and 4 – cathode electrodes (2 – grid); 3 – anode; 5 – tube for gas incoming; 6 – magnetic solenoid; 7 – intermediate accelerating electrode being under the potential versus the ground; 8 – grounded electrode

The ion accelerating and forming system is the three electrodes, axial-symmetric one. For decreasing of the back electron flux from the ion drift space, inducing parasitic loading of high voltage source, emission electrode heating, appearance of X-ray radiation (the last two effects may induce breakdowns in the accelerating gap) the negative potential which is 5...10% of accelerating one is applied to the intermediate electrode 7. The electrode 8 is grounded. The geometry of accelerating and forming electrodes has been chosen in accordance with recommendations given in the work [4].

The ion source is joined to the 500 mm diameter chamber of 500 mm length.

To measure the ion beam profile in the chamber, two normal each other lines of Faraday cups (8 in every line) are placed symmetrically versus chamber axis. These lines are fastened on the copper cooled by water disc of 245 mm in diameter and thickness of 2 mm. There is the orifice in the copper disc through that the central part of ion beam passes to an analyzer.

The high vacuum pump with the water jalousie trap has the speed of pumping about 500 l/s. As an operating liquid in it the polyphenil ethier of N-PFE mark is used.

The typical ion source parameters for which the current near the maximum is generated are given below.

Operating mode	Continuous
Kind of ions generated	Nitrogen ions
Ion energy (keV)	50
Ion current (mA)	25
Discharge voltage (V)	700
Discharge current (A)	0.4
Magnetic field in discharge (Tl)	0.02
Pressure in ion drift space (mPa)	8
Gas input (m3mPa/s)	4

For the diameter of the output hole 12 mm and accelerating voltage of 50 kV the maximal accelerated ion current is 25 mA. During movement in the drift space such beam increases its diameter approximately linearly to the distance passed. At a distance of 725 mm from the output hole the beam diameter is approximately equal 250mm. The ion current density homogeneity is not worse than 5% inside the circle of 200 mm in diameter. The spectrum of the accelerated ions is shown in Fig.3.

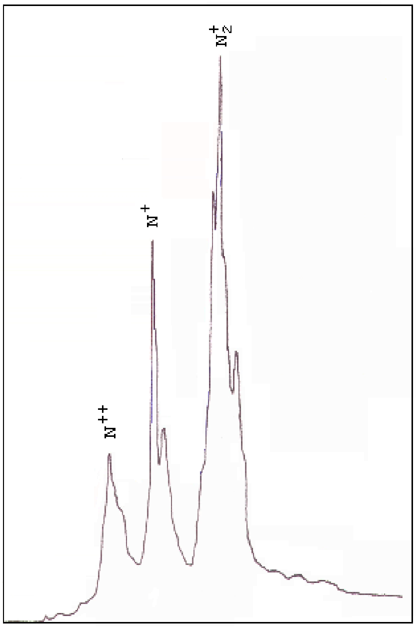

Fig.3. Dependence of ion current on the output of the magnetic mass analyzer on the current of winding of the deflected electromagnet

For the accelerated current more than 30 mA melting in the central part of the stainless still grid occurs, induced most likely by electrons, which are formed in the accelerating gap and move towards ions.

Estimations show that in our case the proposed ion extraction scheme reduces neutral gas incoming from the discharge chamber approximately in one order of value.

Such sources may be used in ion implanters and devices for ion beam assisted film deposition. for generating high current ion beams with energy less than hundred of keV (reducing gas incoming probably will allow to increase energy of received ions in the case of gas pumping through the accelerating tube). They also can be used as injectors for high current linear accelerators.

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ИСТОЧНИК ИОНОВ РЕАКТИВНЫХ ГАЗОВ С ПОНИЖЕННЫМ НАТЕКАНИЕМ НЕЙТРАЛЬНОГО ГАЗА

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Описан ионный источник с оригинальной системой извлечения ионов из разрядной камеры, позволяющей более чем на порядок снизить натекание нейтрального газа в камеру ускорения и использования ионного пучка. Приведены параметры получаемых пучков ионов азота и возможные варианты применения таких источников.

ДЖЕРЕЛО ІОНІВ РЕАКТИВНИХ ГАЗІВ ІЗ ЗНИЖЕНИМ НАТІКАННЯМ НЕЙТРАЛЬНОГО ГАЗУ

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Описано іонне джерело із оригінальною системою добування іонів з розрядної камери, що дозволяє більш ніж на порядок знизити надходження нейтрального газу в камеру прискорення і використання іонного пучка. Приведені параметри отриманих пучків іонів азоту та можливі варіанти застосування таких джерел.