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IMPROVEMENT OF PENNING ION SOURCES

A.A.Bizyukov, Vl.V.Bobkov, A.Y.Kashaba, K.N.Sereda
Kharkov National University, Faculty of physics and technologies, 31 Kurchatov Ave., Kharkov, 61108, Ukraine. E-mail: ***bizyukov@pht.univer.kharkov.ua***

It is shown that the loss of a longitudinal symmetry of magnetic field distribution in respect to the centre of the Penning discharge system causes change of electrostatic potential distribution in the discharge gap leads to appearance of asymmetry of current magnitude to the cathodes of the Penning cell, change of magnitude of current density and energy distribution of the ion beam extracted in a longitudinal direction. The use of an inhomogeneous magnetic field which is longitudinally asymmetrical concerning electrodes of the system allows to increase current efficiency of Penning ion sources from 0,2 to 0,55.

INTRODUCTION

The ion sources on the basis of a gas discharge with oscillating electrons (Penning discharge) and extraction of ions along a magnetic field are widely used due to a low working pressure, high gas profitability, capabilities of formation of ion beams with a large current magnitude [1]. At the same time, the traditional design of such discharge system, characterized by symmetry electrical and magnetic fields concerning center of a discharge system in longitudinal direction, results in a symmetrical distribution of electric potential of plasma with maximum value in center on each magnetic surface. The ions are generated in volume of gas discharge and are accelerated by a longitudinal electrical field to cathodes of a Penning cell. With a symmetrical potential distribution the ion current from a plasma volume also is uniformly distributed between cathodes of a Penning cell. In ion sources with an oscillation of electrons and longitudinal extraction only part of ions is injected through a aperture in one of cathodes, that is the cause of low current efficiency of such systems which are not superior 0,1 [2].

One of probable ways of current efficiency increase of ion sources on the basis of Penning discharge is the formation of an asymmetrical longitudinal potential distribution in plasma of a gas discharge and acceleration of ions from a plasma volume predominantly in a direction of the cathode-extractor of a beam. Such potential distribution is possible to form with the help of an inhomogeneous axial magnetic field, which, as shown theoretically and experimentally in Ref. [3, 4], allows to form and to support an electrical field in plasma volume, irrelevant with influencing of electrods.

EXPERIMENT DESCRIPTION

Experimental research of current efficiency of ion source with Penning discharge with varied longitudinal distribution of magnetic field were caryed out on the device, wich is shown in fig. 1.

The ion source consists of a cylindrical tube, inside which on insulators the electrodes of the Penning cell are built-on. The anode of the Penning cell is a hollow cylinder of length 28 *mm* and inner diamater of 19 *mm* made from a stainless steel. At such sizes of an anode the length-to-diameter ratio makes 1.5, that provides optimum conditions for ionization in volume of gas discharge with oscillating electrons [3]. The flat cathodes with diameter of 30 *mm* make from a stainless steel were mounted symetricaly concerning anode on the distance of 4 *mm*. The cathodes had axial apertures with diameter of 2 *mm*, which were used for a injection of an ion beam

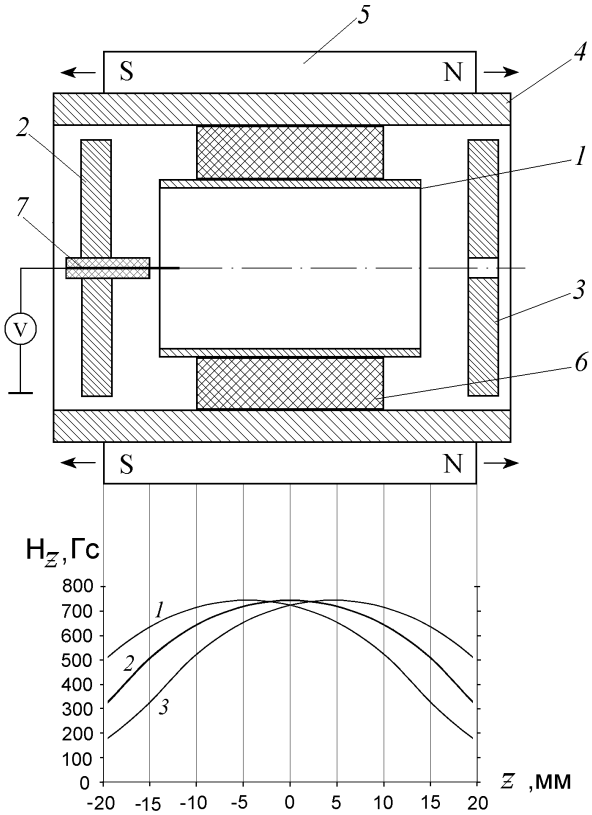

Fig. 1. The scheme of the experimental device (1– anode of the Penning cell; 2, 3– cathodes; 4– tube meke from staneless steel; 5– ring-type permanent magnet; 6– insulator; 7– electrical probe) and distribution of intesity of axial component of a magnetic field on an axis of a system at three positions of a magnet concerning an anode.

and input in a discharge gap of electrical probes. The magnetic field formed by a ring-type constant magnet by an altitude of 40 *mm* established is coaxial to an anode on the ion source. In longitudinal direction mag-

net could displace concerning center of an anode of the Penning cell on spacing interval of 20 *mm*. The distribution of intensity of axial component of a magnetic field on the axis of a system at three positions of a magnet concerning an anode is shown also in fig. 1.

The ion source was established on the vacuum installation of a UVK-type and up to pressure 10^{-5} *Torr* was evacuated. The positive potential by value 1–4 *kV* fed on an anode (cathodes were grounded), that provided a stable combustion of discharge in the Penning cell in pressure range $5 \cdot 10^{-5} \div 10^{-3} Torr$ with usage as working gases of argon, oxygen, azote.

In experiments voltage and discharge currents (on an anode and cathodes) were measured. With the help of the single Langmuir probe the potential of plasma on an axis of a discharge system was measured. The current of an ion beam leaving in a aperture of the cathode-extractor was measured with the help of a Faraday cylinder, and its energy distribution function – with the help of a cylindrical energy analyzer.

DISCUSSION

The experiments demonstrate, that the disturbance of a longitudinal symmetry of distribution of a magnetic field concerning center of a discharge system produces change distribution of an electrostatic potential in a discharge gap, appearance asymmetry of value of currents on cathodes of the Penning cell, change of value of a current density and distribution function of an ion beam leaving in longitudinal direction. In fig. 2

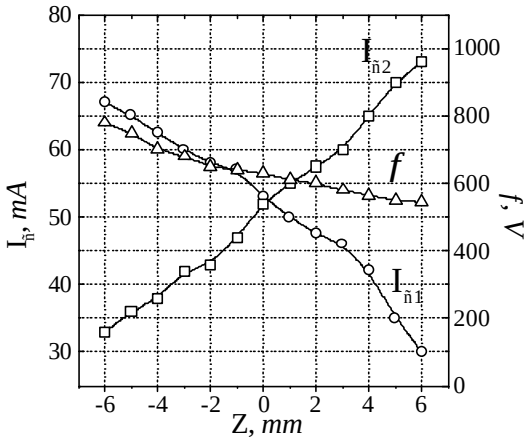

Fig. 2.

the relations of currents on cathodes of the Penning cell and electrostatic potential on an axis of a discharge system on a shear of an anode are shown depending on displacement of center of magnetic system (coordinate of maximum intensity of an axial component magnetic field) from center of an anode of a discharge system. In absence of displacement with a symmetrical distribution of a magnetic field concerning electrodes of a discharge system the current is uniformly distributed between cathodes. With disturbance of a symmetry the discharge current is redistributed between cathodes, being increased on the cathode, which is in a more gentle magnetic field. Thus is proportional to a current on the cathode-extractor the current of an ion beam changes also. To increase of a beam current there corresponds reduction a magnetic field near the cathode-extractor.

The electric potential changes proportionally to magnetic field. With displacement of a magnet system within the limits of ±5 *mm* concerning center, the current on cathodes changes more than two times, and electric potential on an axis of a discharge system within the range of 20–30 %. The probe measurements also demonstrate, that inside an anode of the Penning cell there is asymmetrical concerning center of an anode a distribution of electric potential.

In fig.3 the change of energy distribution function of beam ions is shown depending on a position of a magnetic system. The shape of a distribution function indicates distribution of ionization speed in space of

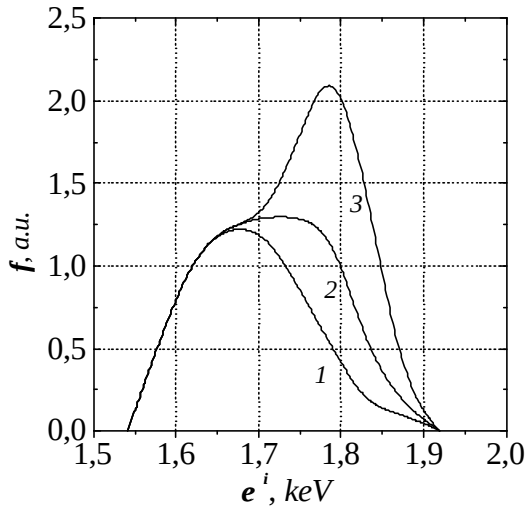

Fig. 3.

the Penning cell, because the energy of ions in the beam is determined by a potential of a point of ion birth. With

displacement conforming to reduction of a magnetic field near the cathode-extractor, from a shape of a distribution function it can be seen, that the increase of a ion beam current and accordingly of current on the cathode-extractor occurs as the expence of increase of generating speed of ions in area with large spatial electric potentials inside an anode of a system. Change of a distribution function of ions and the change of a potential distribution inside an anode at change of a magnetic field allow to draw a conclusion, that an asymmetry of currents on cathodes and concerned with it change of a beam current are conditioned by change of value of a plasma volume, from which the ions are accelerated on the distant cathode. In longitudinal direction for each of cathodes this volume is limited by a condition $0 < j < j_{\max}$ where $\ddot{o}$ -the potential on the given magnetic surface. The appearance of an asymmetry of localization $j_{\max}$ concerning center of a discharge system

results in appearance of an asymmetry of ion fluxes on cathodes and features of a energiy distribution function of ions.

SUMMARY

Thus, the application of an inhomogeneous magnetic field, longitudinally asymmetrical concerning electrods of a discharge system allows to increase current efficiency of ion sources with the Penning discharge. This method was applied at mining a multicellular ion source for etching and deposition of thin-film coatings [6], that has allowed to increase its current efficiency with 0.2 up to 0.55.

REFERENCES

[1] I. Braun, Physics and technology of ion sources, M.: Mir, (1998), 496 p.
[2] Ì .D. Habovich, Physics and engineering of plasma sources of ions, M.: Atomizdat, (1972), 304p.
[3] À.I. Morozov, Plasma accelerators and ion injectors, M.: Nauka, (1984), 272 p.
[4] R.À. Demirhanov, Y.V. Kursanov, L.P. Skripal', G.V. Kharin, Obtaining of flows of energetic ions from discharge with a high heat of electrons in an inhomogeneous magnetic field., Plasma accelerators, M.: Mashinostroyeniye, (1973), 312 p.
[5] R.P. Babertsyan, E.S. Badalyan, G.À. Yegizaryan, E.N. Ter-Gevorkyan, Mechanism of influencing of geometrical parameter on the electrical characteristics Penning ion source, Zh. Tech. Phys., (1998), v. 68, ¹ 9, p 29.
[6] A.A. Bizyukov, A.Y. Kashaba, K.N. Sereda, A.Ph. Tseluyko, N.N. Yunakov, Multichannel source of synthesized ion-electrone flow, Rev. Sci. Instrum, (1996), 67 (12), p. 4117.

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