CURRENT COMPENSATION OF HYDROGEN ION BEAM EXTRACTED FROM PIG WITH METAL-HYDRIDE CATHODE

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The effect of extracted hydrogen ion beam compensation from reflective discharge with metal-hydride cathode that sufficiently widens the possible field of applying plasma sources of such a type is found. The evolution of energy distribution function of ions extracted along the axial direction from reflective discharge with metal-hydride cathode depending on external parameters of the discharge is investigated. The electron distribution functions which compensate hydrogen ion beam are determined.

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1. INTRODUCTION

At a treatment in high vacuum by positive hydrogen ion beams of badly conductive or conductive but insulated matters the accumulation of charge on the surface often leads to ion reception abortion toward the surface or ions receipt with lower energy [1]. In view of this fact the problem of neutralization of ion beam charge is paid the special attention. As a compensated component mainly electrons generated with the help of filament emitters set on the way of ion beam are used. However, using filament emitters limit the term of unbroken work of devices. Therefore the one of the actual problem at surface treatment by ions is preventing or at least weakening the positive volume charge of the beam. The one of the most efficient methods of solving this problem is current compensation of ion beams.

In this work the experimental investigations directed on physical processes studying which are responsible for positive hydrogen ion beam compensation extracted in axial direction from reflective discharge with metal-hydride $Zr_{50}V_{50}H_x$ cathode are presented. The main advantages of such compounds are high density hydrogen packing in metallic matrix, the possibility of long term storage and realizing the hydrogen supply in wide pressure range. Furthermore in this case the opportunity of power inputs decreasing on excitation, dissociation and ionization of molecules and atoms of hydrogen at the expense of metal-hydride activation is possessed [2].

2. EXPERIMENTAL SETUP

The experiments were carried out on an installation that is shown schematically in a Fig. 1. The electrodes of reflected discharge were placed inside quartz cylinder. The total length of a discharge cell was 70 mm. The metal-hydride cathode (4) was performed in a form of a disk electrode with a diameter of 20 mm and a width of 5 mm from $Zr_{50}V_{50}H_x$ getter alloy saturated with hydrogen. The maximum amount of the accumulated hydrogen in such electrode was 229 cm^3 at standard conditions. The second cathode (5) was made from copper. In verifying experiments two copper cathodes were used. In the center of both cathodes were holes 6 mm in diameter. Behind them energy analyzers (6, 7) for energy spectrum of extracted ions investigation were placed. For registration of charge particle beams intensity the energy analyzers were changed on Faraday cups.

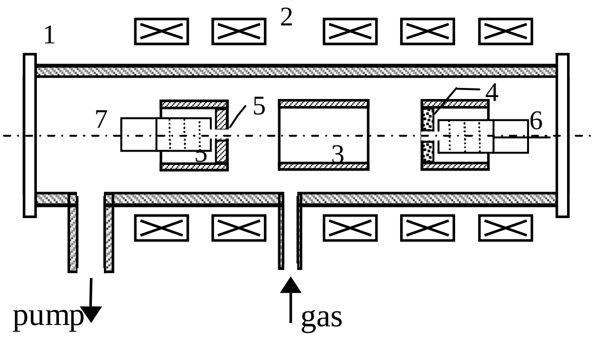

Fig. 1. The scheme of experimental device: 1 – vacuum chamber, 2 – magnetic system, 3 – anode, 4 – metal-hydride cathode, 5 – cupper cathode, 6,7-energy analyzers

3. RESULTS AND DISCUSSION

The dependences of charge particle current extracted from the discharge in axial direction on discharge voltage drop are presented in Fig. 2. The character of extracted charge particle current in case of two copper cathodes applying (Fig, 2, curve 1) repeats the course of discharge current on current voltage characteristic for reflective discharge and agreed with the results of [3].

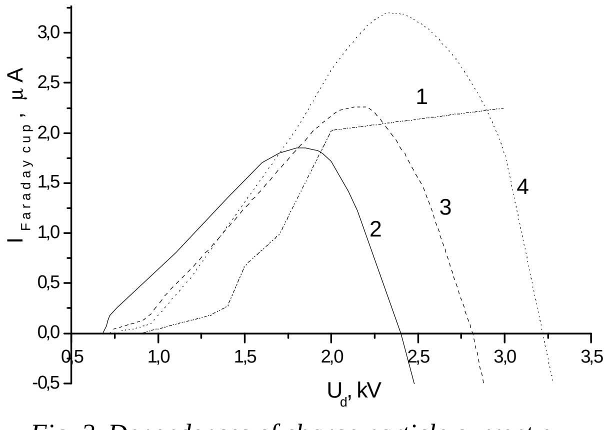

Fig. 2. Dependences of charge particle current extracted along the magnetic field from reflective discharge from the direction of metal-hydride cathode on discharge voltage drop:
1 – copper cathode, P = 3·10^{-4} Torr; H=600 Oe;
2 – metal-hydride cathode, P = 3·10^{-4} Torr; H=600 Oe;
3 – metal-hydride cathode, P = 3·10^{-4} Torr; H=800 Oe;
4 – metal-hydride cathode, P = 3·10^{-4} Torr; H=1 kOe

In case of metal-hydride using as a material of the cathode the extracted ion beam current behavior sufficiently differs (Fig. 2, curves 2, 3, 4). Starting from the magnitudes of discharge voltage drop of $U_d \geq 2$ kV practically linear decreasing of charged particle current on the Faraday cup is observed and at certain magnitude of discharge voltage drop, which depends on magnetic field intensity and pressure of working gas, the total ion current beam compensation is realized. The further increasing of anode voltage leads to changing sign of extracted charge particle beam and it became negative.

It should be pointed out that at increasing of working pressure or intensity of exterior magnetic field the ion current compensation shifts to the direction of higher magnitudes of discharge voltage drop.

Such a behavior of current extracted from the reflective discharge is conditioned by anomalously fast-moving electrons appearing at some conditions [4]. However in our experiments the current compensation was observed only at metal-hydride cathode applying in the working pressure range of $P = 1{\cdot}10^{-5}$- $7{\cdot}10^{-4}$ Torr when the discharge voltage drop had exceeded some threshold level. The magnitude of this threshold level depended on exterior magnetic field intensity and the pressure of working gas as well.

Moreover, when the ion beam was extracted through the hole in the center of copper anticathode (at the presence of metal-hydride cathode) this phenomena was not observed.

The evolution of energy distribution function of ions extracted from the discharge in axial direction depending on regimes of discharges working was carried out (Fig. 3). The curve 1 corresponds to the maximum of the

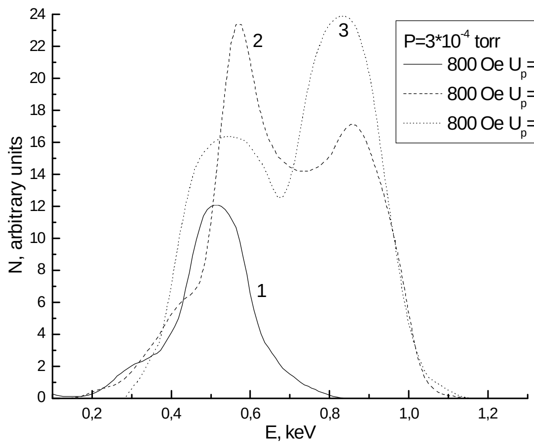

Fig.3. Ion energy distribution function extracted along the magnetic field from reflective discharge with metal-hydride cathode

positive current on Faraday cup. The curve 2 corresponds to current compensation regime. The curve 3 corresponds to negative current on Faraday cup (see Fig. 2). One can see in the first case the distribution function is close to Maxwellian one and the particles quantity and most likely energy are minimal. In case of compensated beams extracting the distribution function has two groups of particles. The most likely energy of low-energy ions is approximately 600 eV, but high-energy ones exceed 800 eV. The quantity of low-energy particles almost in a half exceeded the high-energy ones. The total particles quantity increased as well. In the third case two groups of particles are observed as well, however the peak of low-energy ions decreased, but high-energy ones rose up.

The presence of low-energy peak on ion energy distribution function in case of metal-hydride cathode applying could be explained by corpuscular hydrogen generation H^+ which concentration distinctly increases in discharges with metal-hydride electrodes [5]. However despite the sufficient increasing of H^+ ions part in discharges with metal-hydride electrodes their concentration relatively to H_2^+ does not exceed the magnitude of 0,01% [5, 6]. Therefore the most probable explanation of observed distribution function behavior is as follows bellow.

In case of saturated with hydrogen metal-hydride cathode applying big quantity of hydrogen is desorbed from such a cathode under the influence of ion bombardment. As it was mentioned above hydrogen is desorbed in activated state, that leads to decreasing of ionization potential on 0.3…0.5 eV and increasing of ionization cross-section in 1.5 times [2]. Accordingly ionization rate in this field increases. Thus, there are hydrogen ions desorbed from metal-hydride cathode in discharge paraxial field where a space potential is about several hundreds volts. As long as ion energy is determined by potential of their generation point then produced hydrogen ions will possess the energy corresponding to the space potential on the discharge axis. Such a behavior was the same in the whole range of working pressure.

For energy spectrum registration of electrons, which leave the discharge and compensate the ion beam, the first grid of energy analyzer was supplied by positive potential. The magnitude of this potential was +1.5 kV.

Typical electron energy distribution functions in case of compensated beams generation are presented in Fig. 4. One can see that, at exterior magnetic field intensity changing the electron most probable energy does not sufficiently changed and corresponded the value of approximately 100 eV. The behavior of electron energy distribution functions at various pressure of working gas was similar.

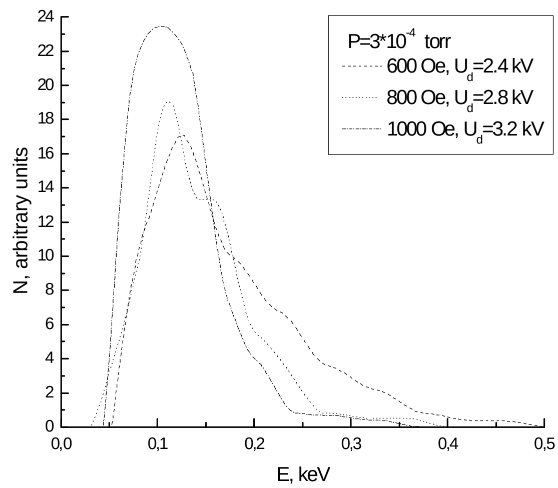

Fig.4. Electron energy distribution function extracted along the magnetic field from reflective discharge with metal-hydride cathode

4. CONCLUSIONS

Thus, the possibility of compensated positive hydrogen ion beams forming from penning type plasma source with metal-hydride cathode is experimentally proved. This phenomenon is conditioned by activation of hydrogen that desorbed from metal-hydride cathode under the influence of ion bombardment of its surface.

The evolution of energy distribution function of ions extracted along the axial direction from reflective discharge with metal-hydride cathode depending on external parameters of the discharge is investigated. It is found the appearing of the low-energy group of ions in case of ion beam compensation regime. This group of ions probably corresponds to the desorbed hydrogen, which was ionized on the axis of the discharge.

The distribution functions of electrons which leave the discharge together with hydrogen ions are determined.

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ТОКОВАЯ КОМПЕНСАЦИЯ ПУЧКА ИОНОВ ВОДОРОДА, ИЗВЛЕКАЕМОГО ИЗ РАЗРЯДА ПЕННИНГА С МЕТАЛЛОГИДРИДНЫМ КАТОДОМ

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Обнаружен эффект компенсации извлекаемого пучка ионов водорода из отражательного разряда с металлогидридным катодом, который существенно расширяет область возможного применения плазменных источников такого типа. Исследована эволюция функции распределения ионов, извлекаемых вдоль магнитного поля из отражательного разряда с металлогидридным катодом, по энергиям в зависимости от внешних параметров разряда. Определены функции распределения электронов, компенсирующих пучок ионов водорода.

СТРУМОВА КОМПЕНСАЦІЯ ПУЧКА ІОНІВ ВОДНЮ, ЩО ВИТЯГАЄТЬСЯ З РОЗРЯДУ ПЕННІНГА З МЕТАЛОГІДРИДНИМ КАТОДОМ

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Виявлено ефект компенсації пучка іонів водню, що витягається з відбивного розряду з металогідридним катодом, що істотно розширює область можливого застосування плазмових джерел такого типу. Досліджено еволюцію функції розподілу іонів, що витягаються уздовж магнітного поля з відбивного розряду з металогідридним катодом, по енергіях залежно від зовнішніх параметрів розряду. Визначено функції розподілу електронів, що компенсують пучок іонів водню.