INVESTIGATION OF REFLECTING DISCHARGE WITH THE SECTIONED METAL-HYDRIDE HOLLOW CATHODE

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In this paper the investigations of Penning discharge with the sectioned hollow cathode in hydrogen environment were carried out. As constructional elements of the hollow cathode the $Zr_{50}V_{50}$ alloy, which is able to absorb hydrogen reversibly was used. Using metal-hydride cathode was shown to allow to reduce the voltage of hollow cathode mode exciting. The possibility of hollow cathode mode operating by means of variation of potentials on its sections was investigated.

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1. INTRODUCTION

Last time the great interest is excited by using gas discharges with hollow cathodes in different fields of science and technology. It is caused by a number of advantages of using this form of cathode in gas discharge devices of different functions. In this case electron kinetic energy emitted from cathode and accelerated in dark cathode layer is efficiently used for gas ionization. Moreover, almost all ions left plasma of negative glow come upon the cathode and take part in process of electron emission from the cathode. At the same time the drastic increasing of discharge current at the constant discharge voltage drop or reducing of discharge voltage at constant current is observed [1-5]. However the differences in physical conditions of discharges having been used by other authors and, as a rule, narrowness of investigated pressure ranges do not allow to establish the basic regularities of physical processes took part in such discharges. Furthermore, nonuniform current distribution along the surface of the hollow cathode, which leads to nonuniform sputtering of the cathode material and reducing of it's lifetime, have been noticed by a number of authors [4,6].

In this work it is offered to use getter hydrideforming material on base of Zr-V alloy as a material of hollow cathode. Application of such reversible sorbents of hydrogen allows significantly reduce erosion of cathode material at cost of forming shielding gas target near the surface of the cathode with following dissipation of particles energy which bombard such cathode. Moreover, desorption of hydrogen from such materials leads to significant reduction of thermal loading as well [7].

At room temperatures, such intermetallic compounds exhibit the equilibrium pressure not exceeding 1–10 *Pa*, the dynamics of sorption-desorption and hydrogen capacity being improved. The decomposition of the hydride phases of the above materials allows to provide for filling hydrogen isotopes in the range of working temperatures 400–900 *K*, and the gas itself releases uniformly. Therefore using such metal-hydrides allows to realize working gas filling directly into hollow of the cathode and thereby to simplify the system of gas feeding.

2. EXPERIMENTAL SETUP

Investigations of the reflecting discharge in hydrogen environment with the sectioned metal-hydride hollow cathode were carried out on the device which scheme is presented on fig.1. The total length of the cell was 70 *mm*. The anode (7) was made from stainless steel and represented itself hollow cylinder 32 *mm* in diameter and 15 *mm* length. The sectioned hollow cathode was made from five-disk electrodes 5 *mm* thick and 20 *mm* in diameter with a hollow in the center 6 *mm* in diameter. The electrodes of the hollow cathode were made from getter powder $Zr_{50}V_{50}$ alloy saturated with hydrogen and pressed with copper binder. The initial hydrogen saturation was 230 g/cm^3 of the alloy at standard condition. These electrodes were electrically insulated from each other through the ceramic insertion 1 *mm* thick. In the comparative experiments hollow cathode from copper with the same construction and dimension was used. The initial working pressure was established at the expense of external hydrogen supply in gas discharge gap or directly through the hollow of

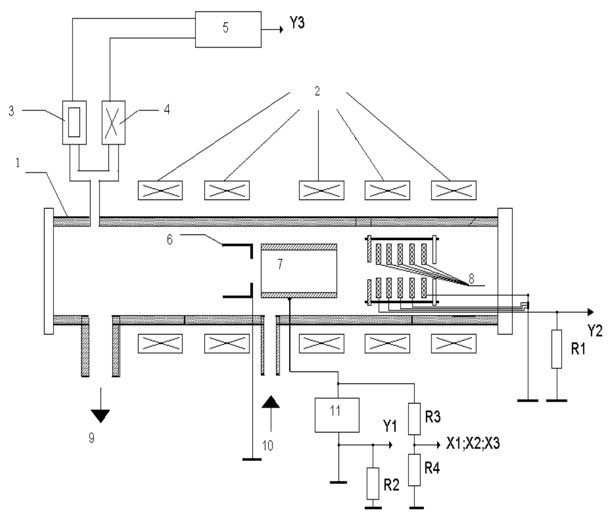

Fig. 1. Installation diagram
1 – vacuum chamber; 2 – magnetic system; 3 – ionizing manometric transformer; 4 – thermocouple manometric transformer; 5 – ionizing - thermocouple vacuum gage; 6 – anticathode; 7 – anode; 8 – set of cathodes; 9 – pumping; 10 – gas supply; 11 – power supply

the cathode. The change of working pressure was realized at cost of hydrogen desorption from metal-hydride hollow cathode under the influence of ion bombardment. Current-voltage characteristics of the discharge and change of working pressure was measured by two-coordinate self-recording devices PDA-1.

3. RESULTS AND DISCUSSION

In process of carrying out of the experiments the current-voltage characteristics of discharge in the pressure range of (2-8)*10^{-4} *Torr* were investigated. At higher pressures of working gas ion current which bombards the cathode significantly increased that led to higher hydrogen emission from metal-hydride at cost of ion-stimulated desorption. As a result the local increase of pressure in the hollow of the cathode took place which led to the transforming of discharge to arc form.

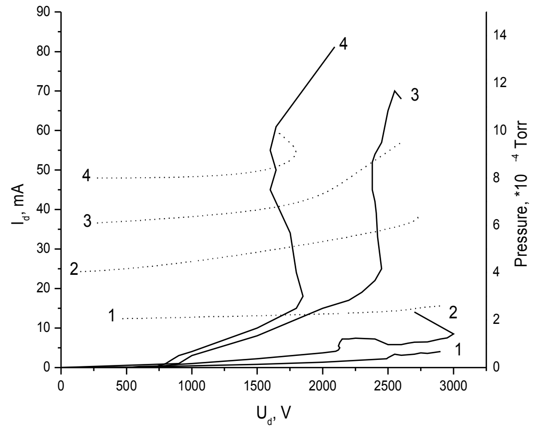

Fig. 2 Current-voltage characteristics of the discharge with cupper hollow cathode (solid curves) and pressure dependencies on discharge voltage. H=600 Oe,
*1. P=2*10┌ Torr, 2. P=4*10┌ Torr,*
*3. P=6*10┌ Torr, 4. P=8*10┌ Torr.*

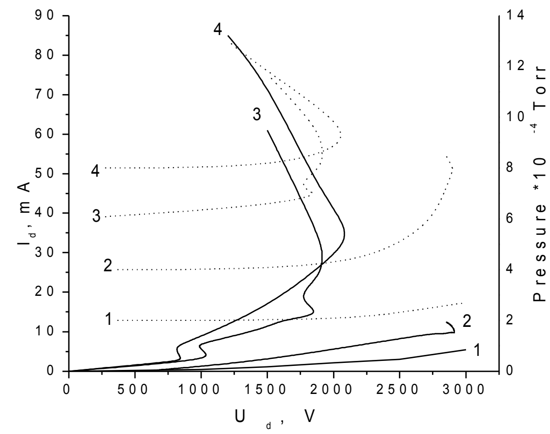

Fig. 3 Current-voltage characteristics of the discharge with metal-hydride hollow cathode (solid curves) and pressure dependencies on discharge voltage. H=600 Oe
*1. P=2*10┌ Torr, 2. P=4*10┌ Torr,*
*3. P=6*10┌ Torr, 4. P=8*10┌ Torr.*

The most typical current-voltage characteristics of the discharge are present on fig. 2 and 3 (*solid curves*). One can see that when using reversible sorbents of hydrogen as constructive material of the cathode the effect of hollow cathode is observed at lesser voltage drop on the discharge in comparison with copper cathode. This fact caused by hydrogen desorption from metal-hydride in vibrationally-exited state, that leads to reduction of ionization potential on 0,5 *eV* [8]. This assumption is confirmed by increasing of working pressure along with increasing discharge current (fig.2 and 3 *dash curves*). In case of using metal-hydride hollow cathode the changing of working pressure is significant and it conditioned by hydrogen desorption from metal-hydride as a result of decomposition of hydride phases. Whereas the working pressure for cupper cathode do not practically change. Hydrogen filling directly into the hollow of the cathode led to significant biasing of excitation potential of hollow cathode mode in lesser values of discharge voltage direction (fig.4). Such behavior was observed for all pressure values and magnetic fields having been used in the experiments.

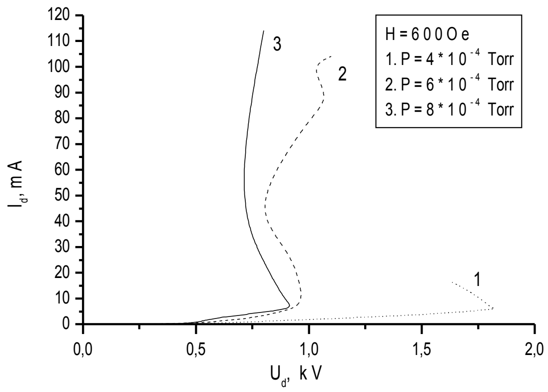

Fig. 4 Current-voltage characteristics of the reflecting discharge with metal-hydride hollow cathode in case of hydrogen filling into the hollow of the cathode

For the purpose of investigating of possibility to operate of hollow cathode mode exciting the feeding of different potentials on the sections of the hollow cathode was realized. In case of the same negative potential on the all sections of metal-hydride hollow cathode the reduction of voltage of hollow cathode mode exciting was observed. At small potentials (up to –0,5 *kV*) the shift on the size of order of applied negative potential was observed. While at higher potentials (up to –2 *kV*) the reduction of voltage did not exceed 1 *kV*.

The behavior of discharge in case of positive potential feeding in the range of 0,5–2 *kV* on the middle section of the hollow cathode (the rest were under ground potential) was investigated. At such potentials feeding on sections of the cathode the case of modified hollow cathode is realized, where complementary anode inside of the hollow is formed. The magnitude of discharge current at that distinctly reduced and biasing of excitation potential of hollow cathode mode in higher values of discharge voltage direction was observed. Such behavior was typical for the whole range of investigated pressures of working gas and was more pronounced at hydrogen filling into the hollow of the cathode (fig.5). In such modified hollow cathode the ion confinement worse in comparison with conventional hollow cathode and therefore higher voltage drop on discharge is realized [9]. This, on the other hand, gives possibility to operate of hole dimension and charge losing in such modified hollow cathode.

4. CONCLUSION

Thus, as a result of carried out experimental investigations of reflecting discharge with sectioned hollow cathode it was shown that using metal-hydride as constructive elements of hollow cathode allows reduce hollow cathode excitation voltage. Hydrogen filling into the hollow of metal-hydride cathode leads to the more significant reduction of hollow cathode excitation potential as well. The possibility of operating of hollow cathode excitation mode by potentials applying on it's sections was shown. Additional negative potential (up to –0,5 *kV*) applying leads to the biasing of hollow cathode excitation voltage on the size of order applied negative potential. Applying of positive potential on the middle section of the cathode leads to decreasing of discharge current and biasing of excitation potential of hollow cathode mode in higher values of discharge voltage direction. At that the possibility to operate of hole dimension and charge losing in it appears.

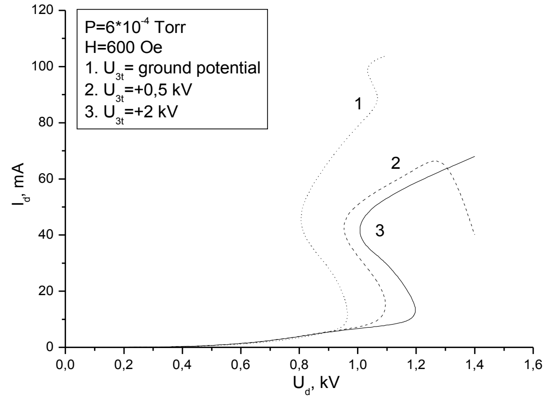

Fig. 5. Current-voltage characteristics of the reflecting discharge with metal-hydride hollow cathode in case of positive potential feeding into middle section of the cathode

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ИССЛЕДОВАНИЕ ОТРАЖАТЕЛЬНОГО РАЗРЯДА С СЕКЦИОНИРОВАННЫМ МЕТАЛЛОГИДРИДНЫМ ПОЛЫМ КАТОДОМ

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В работе проведены исследования разряда Пеннинга в среде водорода с секционированным полым катодом. В качестве конструкционных элементов полого катода использовался сплав $Zr_{50}V_{50}$, способный к обратимому поглощению водорода. Показано, что применение металлогидридного полого катода позволяет уменьшить напряжение возбуждения эффекта полого катода. Исследована возможность управления режимом полого катода путем варьирования потенциалами на его секциях.

ДОСЛІДЖЕННЯ ВІДБИВНОГО РОЗРЯДУ З СЕКЦІОВАНИМ МЕТАЛОГИДРІДНИМ ПОРОЖНИСТИМ КАТОДОМ

В.М. Бориско, Є.В. Клочко, І.М. Середа, О.Ф. Целуйко, Д.В. Зінов'єв

У роботі проведені дослідження розряду Пенінга в середовищі водню із секціонованим порожнистим катодом. Як конструкційні елементи порожнистого катода використовувався сплав $Zr_{50}V_{50}$, здатний до оборотного поглинання водню. Показано, що застосування металогидрідного порожнистого катода дозволяє зменшити напругу збудження ефекту порожнистого катода. Досліджено можливість керування режимом порожнистого катода шляхом варіювання потенціалами на його секціях.