Source of Low Temperature Gas Plasma with a Wide Range of Parameters[1]

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Abstract – The modernization of "PINK" plasmagenerator was carried out. It included the introduction of discharge initiation unit in its construction. The investigations of modernized plasmagenerator work were conducted. The dependences of current distribution between two parallel working plasma-filled discharge gaps at different pressures and cathode heating current were obtained and explained. It was shown that introduction of initiation unit allows to expand the ranges of plasmagenerator stable work on pressure and discharge currents significantly.

1. Introduction

Recently the vacuum-plasma technologies of materials and production surface modification have wide using in industry. Such technologies include the deposition of strengthening, protective and decorative coatings, diffusive saturation of treated surface by metal and gas ions, ion implantation to the surface and other processes.

At the realization of these technologies often it is necessary to get homogenous plasma in vide volumes, at that they use ions extracted from cathode and anode regions of low pressure discharges. Fo such plasma generation high-frequency and microwave-discharges, vacuum arc discharge, glow discharge in closed electric and magnetic fields, and non self-sustained low pressure arc discharge with a heated electrode.

For these aims the source of low-temperature arc-discharge plasma of low pressure was developed in the laboratory of plasma emission electronics of HCEI SD RAS [1]. However during it operation we ascertained that along with the most important advantages including the possibility of plasma creation in volumes up to 1 m^3 density up to 10^{10} sm^{-3} with the homogeneity not worse than ±15 % of the average value and the reliable performance this source has disadvantages, such as impossibility of preliminary installation of necessary discharge parameters in the moment before its initiation, also plasmagenerator instability at pressures less than 0,1 Pa and at discharge currents less than 10 A.

To provide the reliable initiation of non self-sustained low pressure arc discharge and expansion of work pressures range and discharge currents of "PINK" plasmagenerator we conduct a modernization of this plasamgenerator. We had an aim to decrease the minimal limit of plasmagenerator work pressure and decrease the limiting current of discharge stable burning. Modernization included the introduction of initiation unit of non self-sustained low pressure arc discharge to the "PINK" plasmagenerator construction. There are investigations results and main parameters of plasmagenerator with expanded functional possibilities in this paper.

2. The description of experimental set up and experiment methods

Initiation unit of non self-sustained low pressure arc discharge is an additional electrode introduced to the plasmagenerator hollow cathode and connected with the anode through the ballast resistor. Trigger electrode was made of the tungsten stick with the diameter of 2 mm and length of 70 mm. The scheme of switching of plasmagenerator equipped by discharge initiation unit is shown on Fig. 1, and the simplified scheme of modernized plasma source is given on Fig. 2.

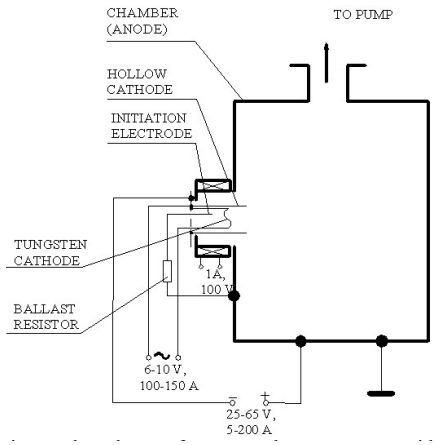

Fig. 1. The scheme of "PINK" plasmagenerator with the discharge initiation unit

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The experiments were carried out on the vacuum ion-plasma set up of НВВ-6.6-И1 type with work chamber sizes of 600×600×600 mm^3 equipped by "PINK" plasmagenerator.

Pumping was conducted by turbomolecular pump providing the blank-off pressure of $1 \cdot 10^{-3}$ Pa.

In experiments process depending on changeable pressure p, filament current I_h and input power we measured discharge current I_d, discharge burning voltage U_d and voltage drop on the ballast resistor U_b. We calculated the current in igniter electrode circuit I_{ign} and the voltage on the cathode-igniter electrode gap U_{ign} from the obtain data. We used argon as a working gas and filled it to the hollow cathode of plasmagenerator.

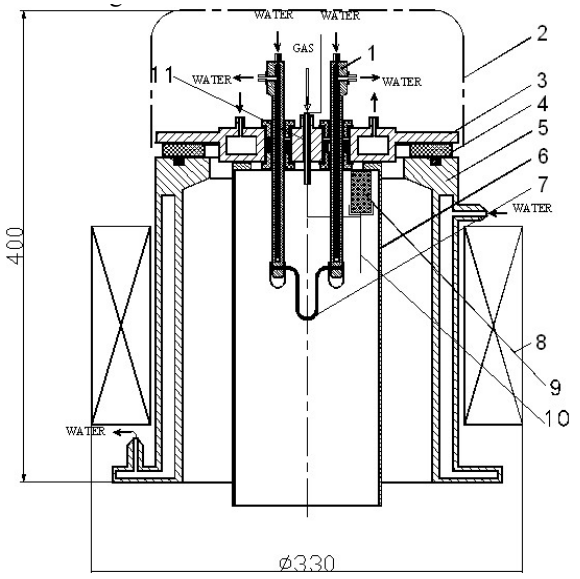

Fig. 2. Simplified construction of "PINK" plasmagenerator equipped by the discharge initiation unit: 1 – cathode holder; 2 – protective cover; 3 – cathode flange; 4 – rubber seal; 5 – body; 6 – hollow cathode; 7 – tungsten heated cathode; 8 – magnetic coil; 9 – ceramic insulator; 10 – tungsten igniter electrode; 11 – ceramic insulating pipe

3. The experiment results and their discussion

As it is clear from Fig. 3 depending on filament current I_h the discharge current I_d is (4÷180) A, and the minimal voltage of discharge burning U_d – accordingly (62÷45) V. At that the curves character was not changed comparing with the usual case for "PINK" without using of ignition system [1].

As that is clear from Fig. 4, at pressure p increase current I_{ign} firstly increases up to 2,2 A. Is it caused by the increase of total current in the system. At that the voltage U_{ign} drops. Then at obtaining of pressure in the chamber of p=(0.08–0.13) Pa (depending on the filament current) current I_{ign} begins to decrease, and voltage U_{ign} at that time increases for filament currents I_h of 105 A and 135 A and decreases for I_h=170 A. such behavior of dependences is explained

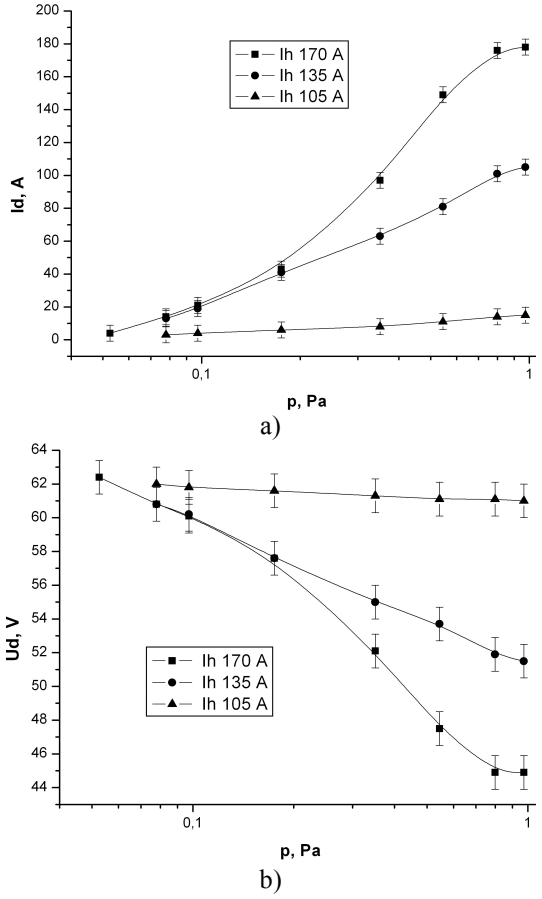

Fig. 3. The dependence of discharge current I_d (a) and discharge burning voltage U_d (b) on work pressure p

by the anode area for the gap of igniter electrode – cathode less than the anode area for the gap of cathode-chamber for three orders. At the anode area less than plasma column area near the anode all column should shrink, and it is necessary for that to increase the electrons density or increase the drift speed. In both cases it is necessary the increased voltage U_{ign} [2]. At the same time due to large (order of 2 m^2) area of the main anode the total voltage of discharge burning can not increase significantly due to the most part of current locks in the chamber used as a hollow anode. As the voltage of cathode-igniter electrodes U_{ign} begins to increase (for filament currents of 105 A and 135 A) the current in igniter electrode circuit decreases, and that leads to the voltage drop U_b on the ballast resistance and in case of filament current of 105 A and 135 A the drop of total voltage of discharge burning U_d can not compensate the. voltage U_{ign} increase. In case of filament current of 170 A the drop of burning voltage U_d is significantly more than the voltage drop on the ballast resistance U_b. Thus the voltage U_{ign}=f(p)decreases, however the canting angle of the U_{ign} curve changes. At increase of the p≈0.5 Pa pressure we observed some growth of the current I_{ign}. It can be caused by the growth speed moderation of plasmagenerator total current.

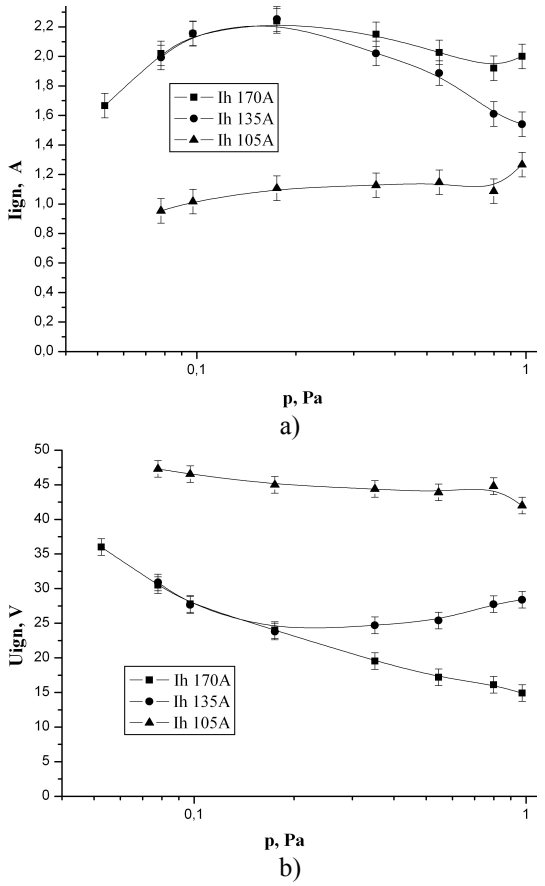

Fig. 4. The dependence of igniter electrode current I_{ign} (a) and the voltage between the igniter electrode U_{ign} and cathode (b) on pressure p in chamber at fixed ballast resistance $R_б$=30 Ohm and. different filament currents I_h

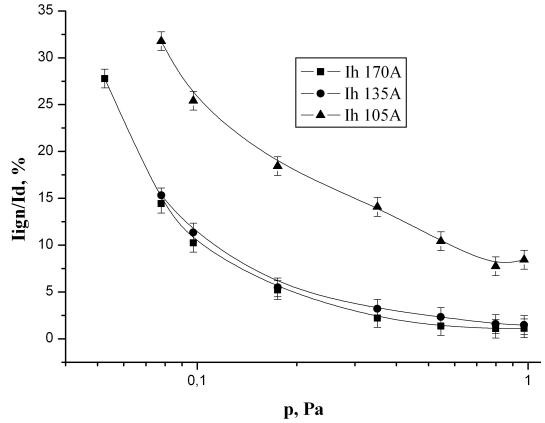

Fig. 5. The dependence of current percentage in the circuit of igniter electrode I_{ign} ($R_б$=15 Ohm) to the I_d total discharge versus p pressure

It is clear from Fig. 5 that versus the pressure in work chamber from 1,5 % up to 33 % of discharge current lock on the igniter electrode. As the pressure increases the smaller part of current locks on the igniter electrode. That is probably caused by increase of the anode drop near the igniter electrode as increase of plasmagenerator total current. The big percent of current locking on the igniter electrode in case of the smaller filament current can be explained by the I_d smaller total discharge current.

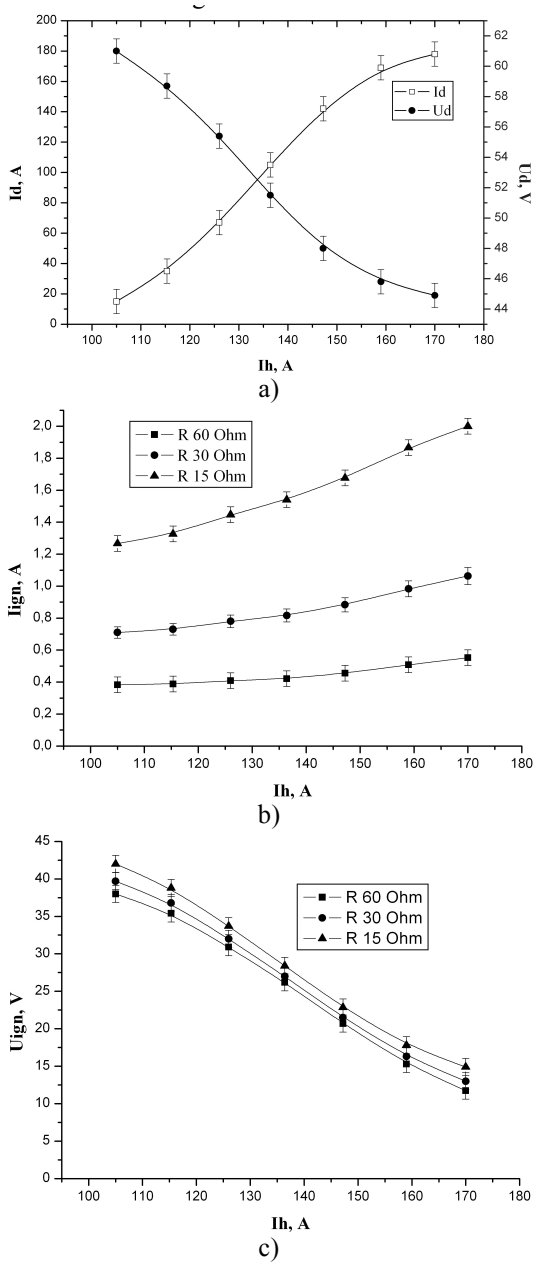

Fig. 6. The dependence of discharge current I_d and discharge burning voltage U_d (a); current, locking on the igniter electrode I_{ign} (b) and the voltage of cathode- igniter electrode gap U_{ign} (c) on the cathode filament current I_h

It is clear from Fig.6 that at filament current increase the current of total system increases, and burning voltage of the main discharge drops, current and voltage on the gap of cathode – igniter electrode behave by analogy.

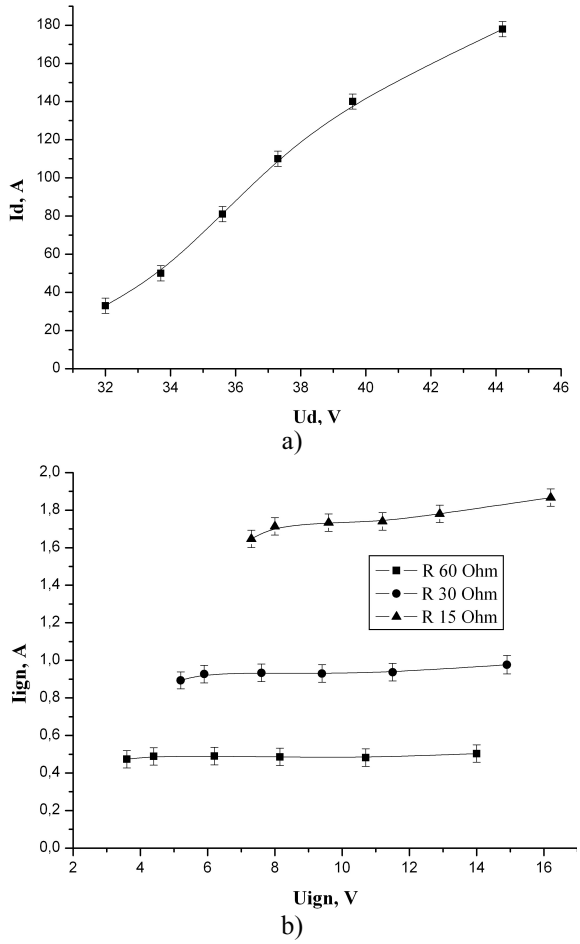

Fig. 7. Current-voltage characteristics of the discharge (a) and cathode-igniter electrode gap (b)

It is clear from Fig. 7 that plasmagenerator current-voltage characteristic is increasing, however it is clear that at input power increase the current locking on the igniter electrode is changed insignificantly versus the voltage on cathode-igniter electrode gap. Such behavior character of curves can be explained by that discharge current growth at input power increase leads to anode drop increase near the igniter electrode and that leads to voltage increase on cathode-igniter electrode gap and limiting of current locking on this electrode.

4. Conclusions

Thus as a result of work:

- a device of discharge initiation considerably simplifying the work with "PINK" plasmagenerator was developed;
- the investigations of modernized source work was conducted, and during it the main parameters of investigated device versus work pressure, filament current and input power were defined;
- the minimal work pressure for "PINK" plasmagenerator was decreased from 0,08 up to 0.05 Pa;
- the dependences of current distribution between two parallel connected plasma-filled discharge gaps at different pressures and cathode filament currents were shown and explained.

Fulfilled modernization of plasmagenerator and conducted investigations allowed significantly expand operating range of parameters and therefore its technological possibilities.

References

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