Extended Arc Plasmagenerator PINK-P[1]

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Abstract – The plasmagenerator, based on non-self-sustained low-pressure arc discharge has been designed for finishing treatment and activation of surfaces and for plasma-assisted vacuum arc deposition of functional coatings. Plasmagenerator allows providing treatment of extended details (l ~ 50 cm). Results of researching the dependence of the discharge current and operating voltage on pressure, on the filament current and magnetic field are presented. This plasmagenerator produces plasma of density ~10^{10} cm^{-3}. With using argon as a working gas maximal discharge current is 135 amperes, and with nitrogen – about 120 amperes. Duplication of filament cathode channels is designed to increase fail-safety of plasmagenerator operation. Adding of longitudinal magnetic field allows increasing of operational stability, decrease of discharge voltage and extend of discharge currents range.

1. Introduction

At vacuum ionic-plasma treatment of extended large-sized products with the help of plasmagenerator "PINK" [1], for archive of uniform processing of products surface with plasma, there is a necessity to install a several plasmagenerators [2].

It involves complication of power supplies and the control systems of plasmagenerators and necessity of application of special actions on improvement of plasma uniformity on working volume. This problem can be solved if to develop the expanded plasmagenerator, capable to create volumetric plasma formations which longitudinal sizes are comparable with the linear sizes of processed products. In laboratory of plasma emission electronics of Institute of High Current Electronics SB RAS such plasmagenerators [3, 4], installed in the centre of the vacuum chamber, have been developed. But the given way of plasmagenerators installation in most cases involves complication of the vacuum chamber design of and details rotation system. Because in most cases, vacuum ionic-plasma apparatus are completed with planetary systems of the details rotation, fastening of plasmagenerators on lateral walls of the vacuum chamber is more preferable. Extended plasmagenerator with the combined filament and hollow cathode, named "PINK-P", installed on the flanges located on lateral walls of the vacuum chamber has been developed by us.

2. Design and power supplies of plasmagenerator

"PINK-P" is a plasmagenerator, based on non-self-sustained low-pressure arc discharge with filament cathode. The design of plasmagenerator "PINK-P" provides its installation on a rectangular landing place with the sizes of an aperture 120×460 mm and the fixing sizes 140×480 mm on ten stud-bolts M6 with step of 120 mm. The drawing scheme of plasmagenerator "PINK-P" is presented in Fig. 1.

Plasmagenerator consists of the water-cooled casing *2* closed by a cover of the hollow cathode *1*. On a cover of the hollow cathode, six water-cooled electro inputs *3* intended for fastening of four filament cathodes *5* are mounted. Cathodes are made of a tungsten wire in diameter 1.5–2 mm. Plasmagenerator is isolated from the vacuum chamber by means of a bushing *6* and is under cathode potential. For prevention of pollution the bushing is covered by the screen *8* which is under the floating potential.

Function of the hollow anode of discharge system is carried out by internal walls of the vacuum chamber. Working gas in plasmagenerator arrives through gas input *4*. Photo of the plasmagenerator is presented in Fig. 2.

The arc discharge in plasmagenerator is non-self-sustained, i.e., its parameters are effectively supervised by emission current of the filament cathodes. The electrons emitted by filament cathodes yield primary ionization of gas which is necessary for ignition and discharge maintenance. At applying of a voltage from the power supply between the hollow anode (the vacuum chamber) and the hollow cathode the non-self-sustained electric arc discharge is ignited.

Imposing of a longitudinal magnetic field with an induction $B \approx 0.02$ T allows to stabilize the discharge and to expand a range of discharge currents.

Using of the combined filament and hollow cathode allows increasing at several times a discharge current, in comparison with the discharge system including only the filament cathode.

The plasmagenerator circuit is presented in Fig. 3.

The plasmagenerator powering is carried out by power supply IPP-150-2 which provides electric powering of discharge and filament cathodes. The discharge power unit represents regulated inverter. The heat current regulator is executed under the scheme of

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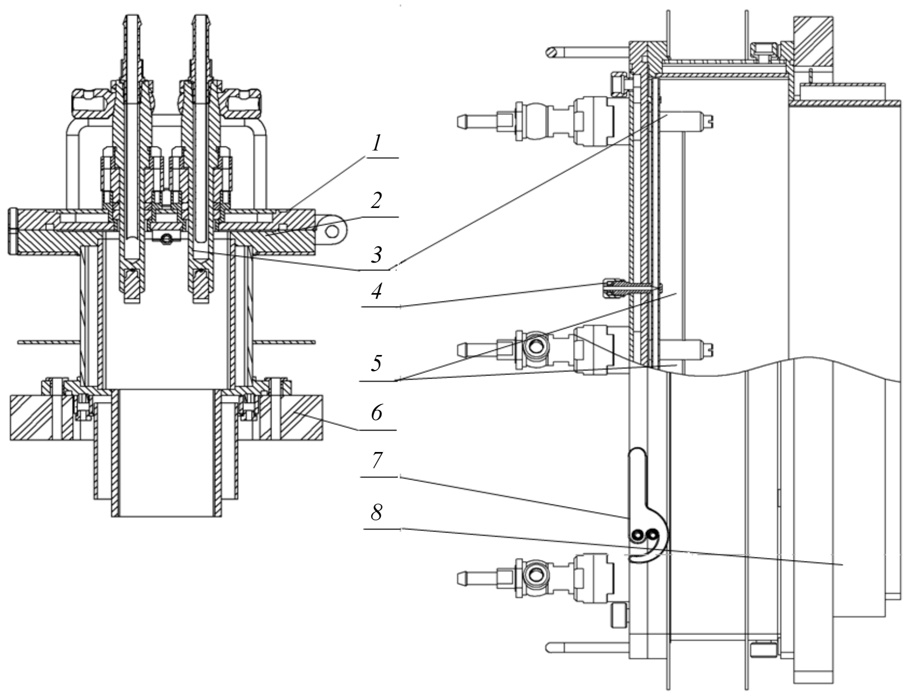

Fig. 1. Drawing scheme of plasmagenerator “PINK-P”: *1* – cover of the hollow cayhode; *2* – casing; *3* – electro input; *4* – gas input; *5* – filament cathodes; *6* – bushing; *7* – clamp; *8* – screen

a uniphase thyristor controller with a bucking transformer on an exit and has two independent channels. The secondary winding of the transformer has tap from a medial point for connection of “minus” of the discharge power supply. It allows to provide symmetry of a current in windings of the transformer and to reduce its dimensions. For increase in reliability of plasmagenerator and support of its continuous work during a work cycle, the plasmagenerator and power unit design provides reservation of the filament cathodes: in a nominal operating mode electricity moves on channels “Filament 1” and “Filament 2”. When burnout of any filament cathode occurs, heating is automatically switched to a reserve line (“R. Filament 1” or “R. Filament 2”).

In a nominal operating mode of plasmagenerator, the discharge burns without formation of cathodic spots, but at the first starts of system, or long breaks in the work, transitions in a mode of burning with formation of a cathodic spots are possible. In such mode the discharge burns in vapors of the cathode material that can lead to pollution of insulators of plasmagenerator by products of the hollow cathode erosion, besides, formation of a cathodic stain on the heated cathode can lead its burnout. For prevention of these situations, the system of arc control is built in a discharge power unit. The system works as follows: during discharge functioning there is a tracing of a current of the discharge and a voltage of its burning.

At excess by a discharge current of 30 A and simultaneous depression a burning voltage less than 25 V the system disconnects a power unit of the discharge from a loading. At work in a manual mode recurring switch on is carried out by the operator, and at remote control – the block monitoring system, thus it is possible to regulate a delay of switching on of the block for support of disintegration of plasma of a cathodic spot and prevention of its recurring occurrence.

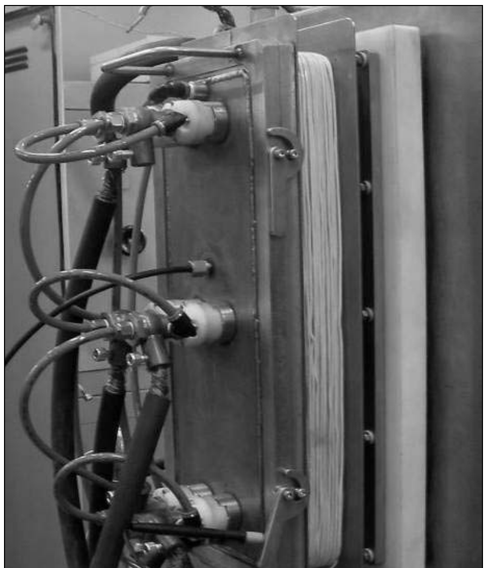

Fig. 2. Photo of the plasmagenerator

The power allocated in the category is up to 7.5 kW, therefore at operation of the given plasmagenerator it is necessary to use water-cooling of the vacuum chamber and plasmagenerator.

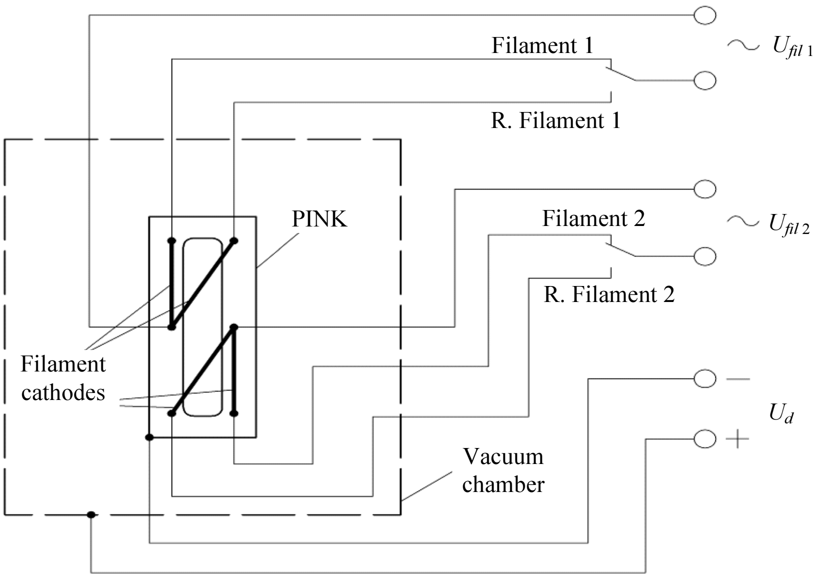

Fig. 3. The plasmagenerator circuit

3. Results and discussion

Plasmagenerator tests were curried out in the vacuum chamber having the sizes 650×650×750 mm, pumped out by the turbomolecular pump to pressure ~ 10^{-3} Pa. Volt-ampere characteristics, and also its dependence on a current of filament cathodes, pressure and sort of gases, and magnetic field were explored at plasmagenerator tests. Diameter of the filament cathodes was 2 mm. Working gases are argon and nitrogen. All volt-ampere characteristics have the growing character, typical for a non-self-sustained discharge. Discharge ignition happens at currents of heat above 50 A in a circuit of each of filament cathodes. The minimum pressure of the discharge ignition is 0.4 Pa. Volt-ampere characteristics at various pressure of argon are presented in Fig. 4. It is visible, that with increase of pressure – voltage of the discharge decreases, also there is possible to achieve of higher discharge currents.

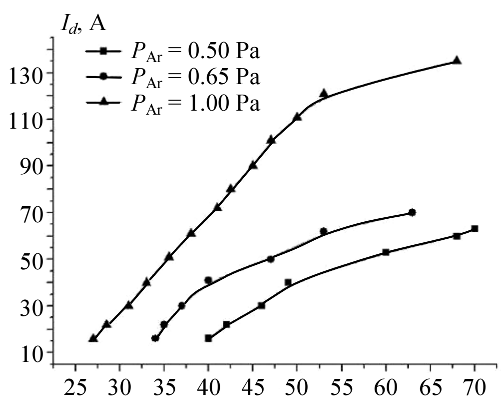

Fig. 4. Volt-ampere characteristics of plasmagenerator at various pressure of argon

Therefore, the maximum current of the discharge was 65 A at pressure 0.5 Pa and already 135 A at pressure 1 Pa.

Dependence of V-A characteristics, on a current of filament cathodes not so big, that shows a Fig. 5.

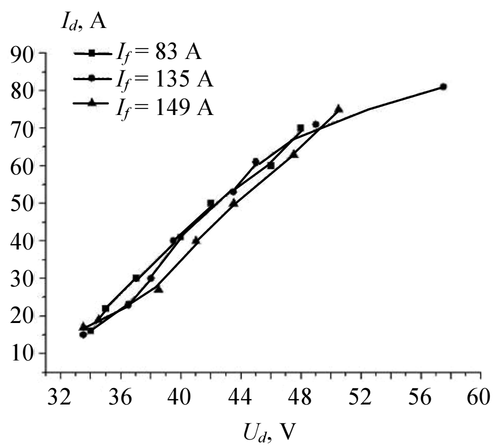

Fig. 5. Volt-ampere characteristics of plasmagenerator at various filament currents

Change of a current of heating almost twice does not lead to considerable change of the discharge voltage. It can be connected with the big values of heating currents, which own magnetic field starts to affect movement of the emitted electrons that does not give them a chance to make effective ionization of working gas.

Adding of a longitudinal magnetic field from the external coil allows stabilizing the discharge, to reduce discharge voltage and to expand a range of discharge currents (Fig. 6).

V-A characteristics at an argon and nitrogen leak-in are presented in Fig. 7.

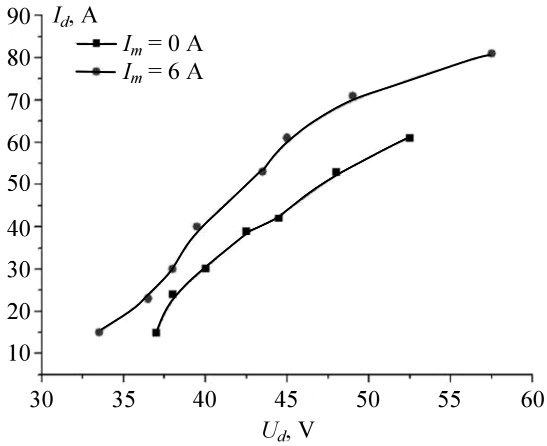

Fig. 6. Volt-ampere characteristics of plasmagenerator at various magnetic coil currents

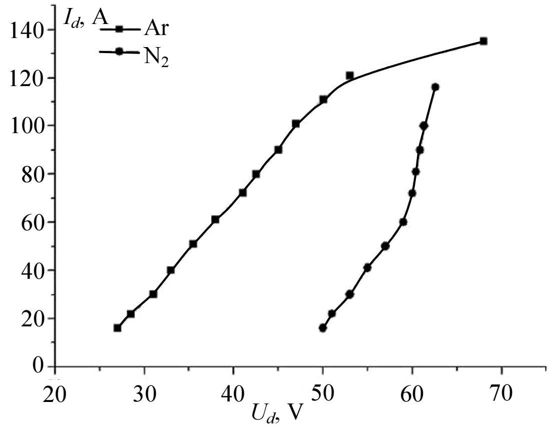

Fig. 7. Volt-ampere characteristics of plasmagenerator at a leak-in of various gases

With using argon as a working gas maximal discharge current is 135 A, and with nitrogen – about 120 A.

4. Conclusion

As a result of carrying out the given work, the extended plasmagenerator has been developed, allowing treating of products with high degree of uniformity of a current density.

The developed plasmagenerator can be used for finishing ionic-plasma clearing and activation of a surface of materials and products, creation of extended nitrided layers and a plasma-assisted deposition of functional coatings.

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