IOP Conf. Series: Journal of Physics: Conf. Series **872** (2017) 012021 doi:10.1088/1742-6596/872/1/012021

Cleaning of the dielectric surfaces using a controlled gas-discharge source of fast neutral particles

A S Fadeev[1], A S Talanov[1], D K Kostrin[1], S A Trifonov[1], A A Lisenkov[2] and V D Goncharov[1]

[1] Saint Petersburg Electrotechnical University "LETI", 197376, St. Petersburg, Russia
[2] Institute of Problems of Mechanical Engineering, Russian Academy of Sciences, 199178, St. Petersburg, Russia

E-mail: lisran@yandex.ru

Abstract. In the present work is proposed the design of a controlled gas-discharge source of fast neutral particles, allowing to clean surfaces of dielectric and semiconductor materials. Also are shown the results of the research of the source main working characteristics.

Development of the gas-discharge sources using fast neutral particles is very relevant. These sources are used in various technological processes at one of the main preparatory stages for cleaning the surface of the substrate before depositing a coating on a dielectric surface [1, 2]. Quality cleaning of a dielectric substrate before spraying of a coating on it is a key to achieving a good adhesion.

Depending on the type of the processed surface and its conductivity, for cleaning prior to coating deposition, are used gas-discharge sources of charged and neutral particles. Cleaning of the dielectric surfaces using the charged particles is impossible due to the charge accumulation on the surface of a workpiece. Collected charge significantly reduces the speed of impact on the surface, up to the complete cessation of the process, and leaves the defects on the substrate surface.

While separating from the gas-discharge plasma the neutral particles and processing the surface by them there are no defects associated with charge accumulation on the surface of a substrate [3]. Therefore, the aim of this work is the design of a controlled gas-discharge source of fast neutral particles. Design of a developed source is shown in figure 1.

The source scheme includes the following components: *1* – system for the supply and pre-heating of a working gas; *2* – solenoid; *3* – anode (source housing); *4* – ceramic insulators; *5* – gas-distributing disk; *6* – massive neutralizer (main cathode); *7* – screen; *8* – treated workpiece; *9* – additional cathode.

In the developed scheme as a working gas is used an inert gas argon. The gas feed system consists of two input tubes, which are heated by the filament coils, and a gas-distributing disk, providing uniform gas supply to the zone of ionization and resonant charge exchange, also it forms the pressure difference between the source volume *A* and the vacuum chamber *B*.

The source electrical scheme includes the main cathode *6*, the anode *3* and an additional electrode *9*. On the main cathode *6* is a negative discharge voltage U_{dis}, while the additional cathode *9* is under a floating potential. The anode *4* (source housing) is grounded. The electrode arrangement shown in figure 1 provides sustaining of the discharge inside the source volume.

As the magnetic field source is used an external solenoid *2*, which provides a directional movement of the charged particles produced in the gas discharge to the neutralizer *6*.

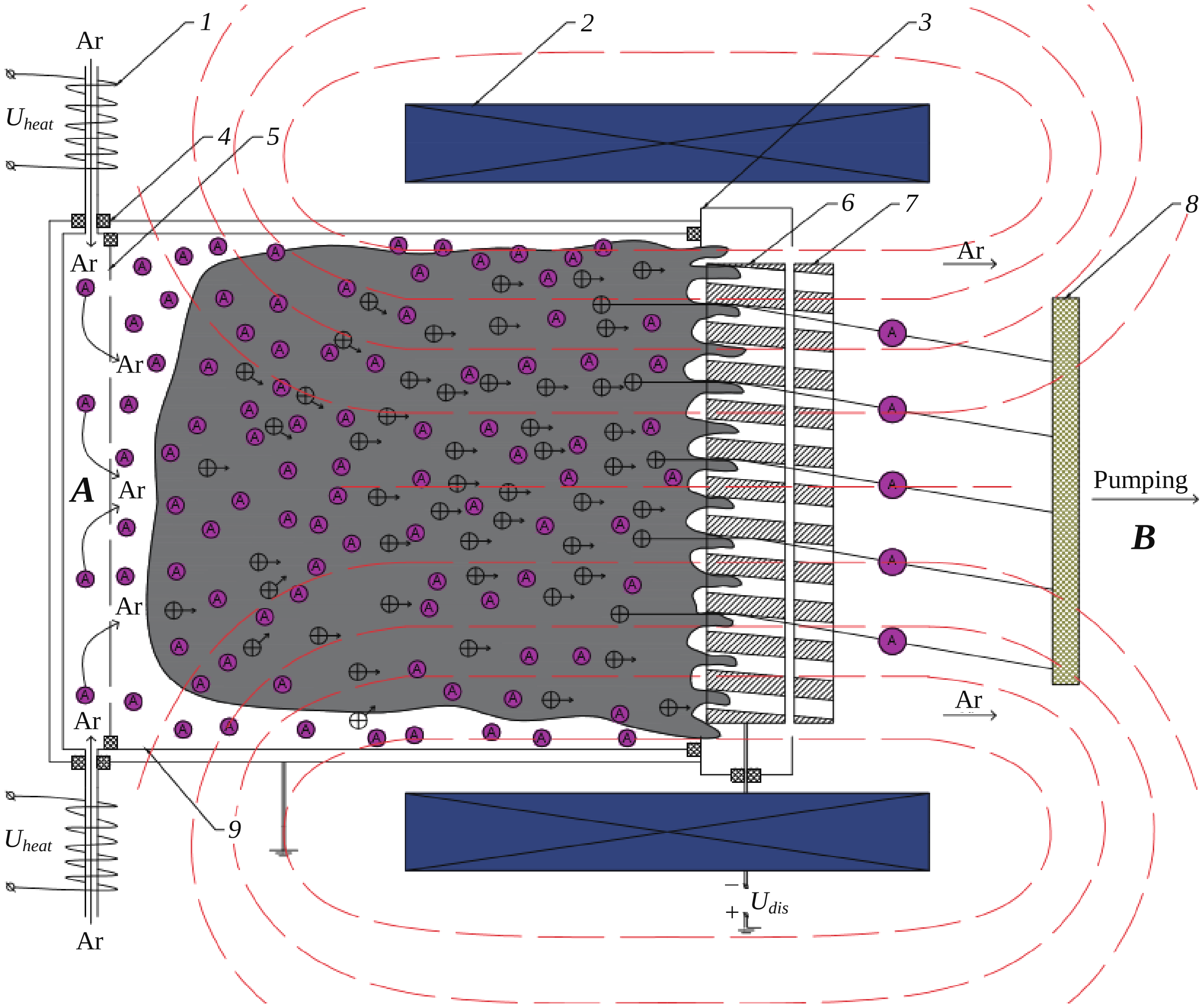

Figure 1. Design of a gas-discharge source of fast neutral particles.

When supplying the working gas into the source volume and applying the negative voltage to the main cathode the gas discharge is ignited, which occupies the entire volume of the source. In the gas discharge are generated the ions that are accelerated by the cathode voltage drop. Neutralization of the charged particles occurs mostly during the reflection of ions from the main cathode, but a small part of ions is neutralized due to the resonant charge exchange on the gas target. As a result of the neutralization process is formed an accelerated flow of neutral particles.

Development of a controlled gas-discharge source of fast neutral particles allowed proceeding to the experimental studies of its performance characteristics. To determine the minimum working pressure of the source has been investigated the dependence of the gas discharge ignition voltage from the pressure in the vacuum chamber $U_{ign} = f(pd)$ at a constant current of 80 mA. The obtained dependence is shown in figure 2.

Analyzing the obtained results can be concluded that the minimum possible pressure at which the source can operate is 0.1 Pa at a discharge voltage of 4.2 kV. Also from the dependence shown in figure 2 it can be seen that at a pressure of 2 Pa or more the discharge ignition voltage does not exceed 800 V and decreases linearly with increasing pressure in the working chamber. Based on the obtained results it was determined the minimum working pressure of the source, which is in the range of 1–2 Pa.

For analyzing the effectiveness of using in the design of a controlled gas-discharge source of fast neutral particles of a shielding disk was investigated the dependence of the ion current incoming at the workpiece from the pressure in the vacuum chamber. The study was carried out with the presence of a disk in the design and without it. The obtained dependences are shown in figures 3–4.

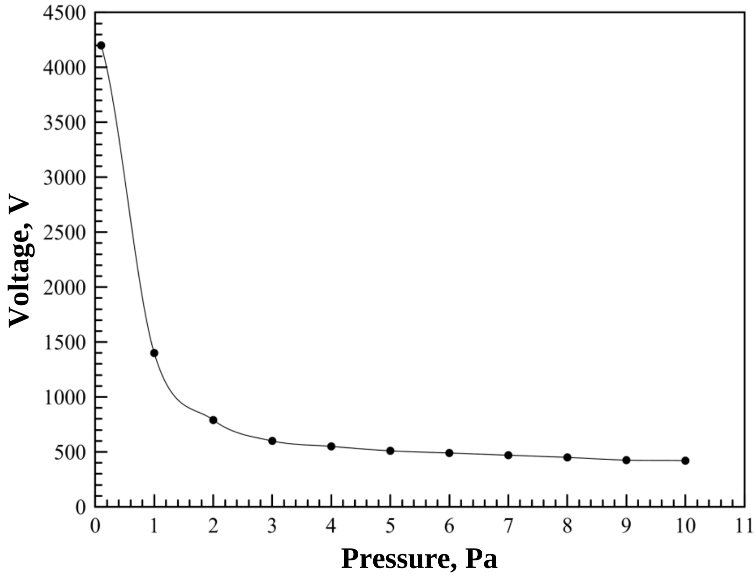

Figure 2. Dependence of the discharge ignition voltage from the pressure in the vacuum chamber.

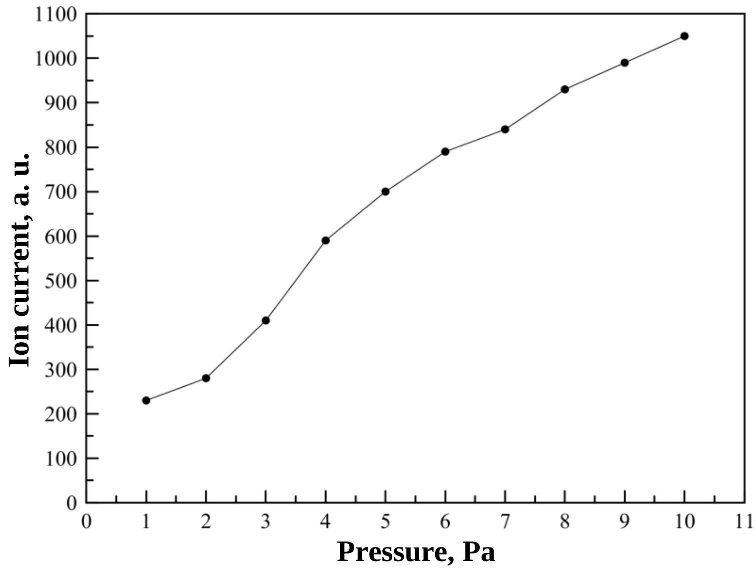

Figure 3. Dependence of the ion current from the pressure in the vacuum chamber without the use of the shielding disk.

As the treated surface in experiments was used a metal probe, having a form of a rectangular plate. Taking into account that the value of the ion current strongly depends on the shape and geometrical dimensions of the probe, and also on the distance between the source and the treated surface, the measurements of the ion current are given in arbitrary units.

Analysis of the obtained data showed that when using the shielding disk the magnitude of the ion current decreases, and also when lowering pressure in the vacuum chamber the value of the ion current decreases almost linearly. Therefore, the use of the shielding disk in the design of the source is a very effective solution for minimizing the amount of the ion current, and, consequently, its effect on the surface of a workpiece.

During the study of the source were obtained dependences of the differential pressure between the vacuum chamber and the volume of the source using two different prototypes of the gas distribution disks. The first prototype of the gas distribution disk have the holes drilled at a distance of 20 mm from the walls of the vacuum volume, for the second prototype this distance is 5 mm. Obtained dependences are presented in figure 5.

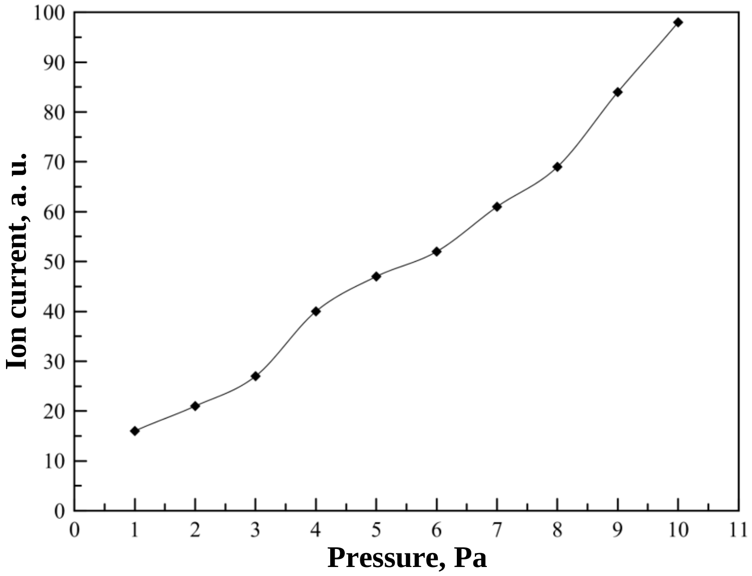

Figure 4. Dependence of the ion current from the pressure in the vacuum chamber with the use of the shielding disk.

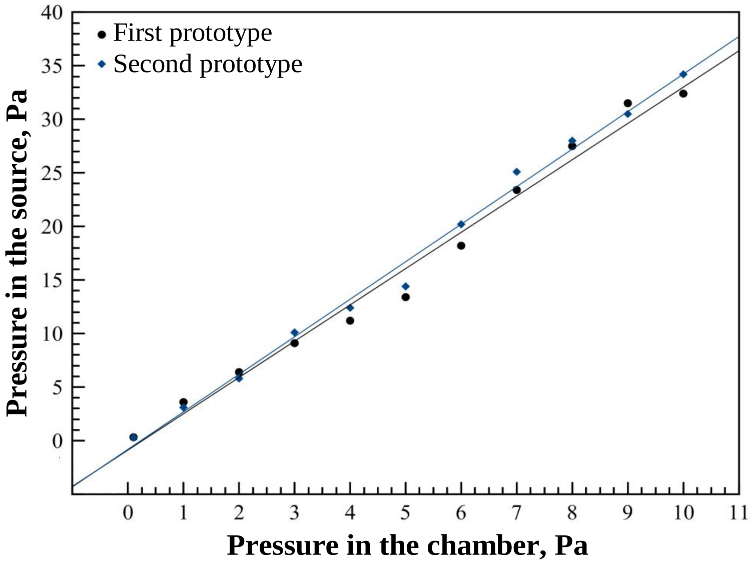

Figure 5. Dependence of the pressure in the source volume from the pressure in the vacuum chamber.

Analysis of the results showed that the use of the gas distribution disk allows creating a pressure differential between the source volume and the vacuum chamber, moreover the pressure in the source is 4 times higher than the pressure in the vacuum chamber. For the gas distribution disks having a different radial location of the holes the results are about the same.

The final phase of the study of a controlled gas-discharge source of fast neutral particles was a finish cleaning of a dielectric part. As the object of cleaning were used samples of borosilicate glass, with a deposited metal layer. After exposure to the flux of neutral particles from the glass surface was completely removed the metal contamination, which cannot be previously detached mechanically. Thus, it can be concluded that the use of a developed controlled gas-discharge source of fast neutral particles for cleaning of the dielectric and semiconductor surfaces is very effective.

References

[1] Barchenko V T, Bystrov Yu A and Kolgin E A 2001 *Ion-plasma technologies in electronic manufacturing* (Saint Petersburg: Energoatomizdat)
[2] Kostrin D K and Lisenkov A A 2016 *Materials Science Forum* **843** 278–83
[3] Shimokawa F, Tanaka H, Uenishi Y and Sawada R 1989 *J. Appl. Phys.* **6** 2613–8