ANODE DIAMETER EFFECT ON IGNITION AND BURNING OF DC DISCHARGE

V. Lisovskiy, E. Skubenko, E. Kravchenko, V. Yegorenkov
V.N. Karazin Kharkiv National University, Kharkov, Ukraine
E-mail: lisovskiy@yahoo.com

This paper studies how an anode diameter value affects ignition and CVC of the dc glow discharge. The decrease in anode diameter is shown to cause a shift of breakdown curves to higher gas pressure and breakdown voltage values and increases the discharge extinction voltage. In the normal mode for moderate anodes the decrease in the discharge current is accompanied with a considerable increase of the voltage across the electrodes. A bright anode glow is found to be present around the small anode in the total range of gas pressure under study.

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1. INTRODUCTION

In order to apply the glow discharge correctly we have to know the conditions of its existence and the qualitative characteristics in various gases, at different gas pressure and electrode size values. In the majority of papers the glow discharge was ignited between flat parallel electrodes of equal area. The anode area was, as a rule, equal to the cross section area of the discharge tube. Presently the literature contains only the data on the effect of the anode shape on the sign and magnitude of the anode voltage drop in long discharge tubes in mercury vapor [1, 2]. However there are practically no data showing the effect of anode size on dc discharge plasma parameters in short discharge tubes. Thus the aim of the work was to study the effect of a flat anode size on ignition and current-voltage characteristics (CVC) of dc glow discharge.

2. EXPERIMENTAL

In order to study the effect of flat anode size on ignition and CVCs of dc glow discharge we employed two discharge chambers, whose schemes are depicted in Fig. 1. In the first case (see Fig. 1, a) the fused silica tube possessed the inner diameter of 56 mm. The cathode diameter was 55 mm. Experiments were performed with flat anodes whose diameter was 55, 5, 3 and 0.8 mm. With small area anodes the tube cross section was closed with a dielectric plate of 55 mm in diameter, through the hole in which the anode was inserted located in one plane with it. The inter-electrode distance was 20 mm. The dc power supply was connected to the cathode, whereas the anode was grounded. The discharge circuit contained the external resistor of 50 kΩ limiting the current and preventing the cathode spot occurrence. Experiments were performed in the nitrogen pressure range of $p = 0.1…10$ Torr with the dc voltages $U_{dc} \le 3000$ V.

In the second case (see Fig. 1, b) the fused silica tube was of 100 mm of inner diameter. Electrodes overlapped the total cross section of the discharge tube. During the experiments a dielectric plate 1mm thick was located on the anode. An orifice of required diameter was perforated at its center. Thus the collecting surface of the anode was limited with this orifice. Experiments were performed anode diameters of 100, 10 and 5 mm. The inter-electrode distance was 32 mm. In this case we employed argon within the pressure range of $p = 0.01 … 10$ Torr.

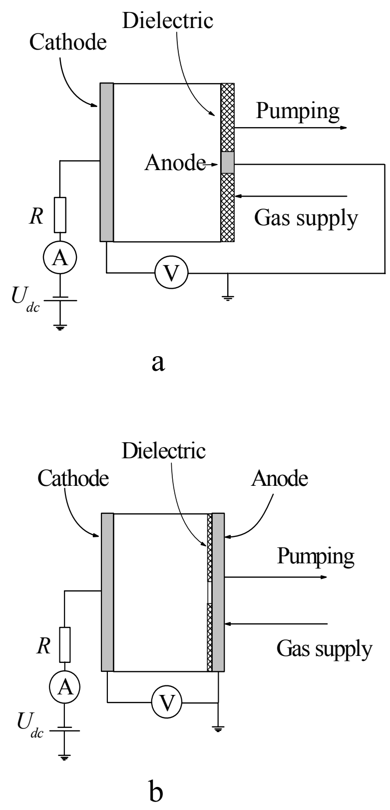

Fig. 1. Scheme of the experimental setup

3. EXPERIMENTAL RESULTS

Fig. 2 depicts breakdown curves of glow discharge in nitrogen in the chamber shown in Fig.1,a and registered for different anode diameters. It shows that the best conditions for discharge ignition are observed when the anode overlaps the total cross section of the discharge tube (the curve for the anode diameter of 55 mm). The minimum of this breakdown curve is located at nitrogen pressure of 0.25 Torr and voltage of 286 V. On decreasing the anode diameter the breakdown curves are shifted to the region of higher gas pressure and breakdown voltage values. So for the anode of 5 mm in diameter the minimum of the breakdown curve is observed at 0.3 Torr and 508 V, and for the anode of 3 mm in diameter the minimum coordinates become 0.33 Torr and 632 V. On decreasing the anode diameter the area of dielectric walls, where electrons may escape due to diffusion increases. Increasing pressure increases the ionization rate and simultaneously decreases the rate of diffusion escape of charged particles to the walls.

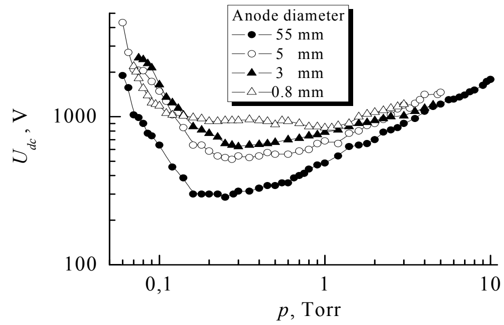

Fig. 2. Breakdown curves of dc discharge in nitrogen with anode diameters of 0.8, 3, 5, and 55 mm

Therefore the decrease in diameter, first, led to the increase of breakdown voltage, and, second, to the shift of the breakdown curve to the region of higher gas pressure. Similar behavior of the breakdown curves is observed with discharge tube diameter decreasing as well as with lowering the emission ability of the cathode. Decreasing the anode diameter leads to the enhanced escape of charged particles to tube walls and the dielectric surface surrounding the anode as well as to the ionization increase near the anode. In a discharge chamber with a small anode the distribution of the electric field becomes strongly nonuniform, and near the anode the electric field intensity increases considerably.

Registering data on breakdown curves of the glow discharge in argon performed in the chamber shown in Fig. 1, b furnished similar results (Fig. 3).

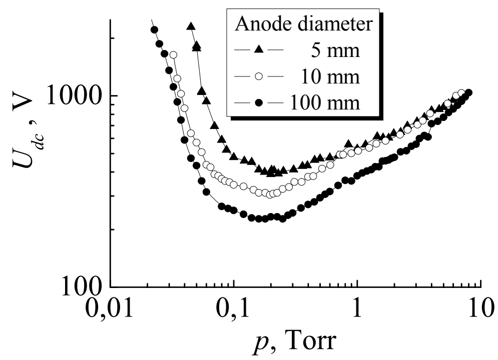

Fig. 3. Breakdown curves of dc discharge in argon with anode diameters of 5, 10, and 100 mm

The breakdown curve for the anode not covered with a dielectric plate possesses the most low gas pressure and breakdown voltage values at the minimum. For the anode covered with the plate with a small diameter orifice the breakdown curve is shifted to the region of higher gas pressure and breakdown voltage values.

Fig. 4 presents CVCs of discharges in nitrogen in a broad range of pressure values for the discharge chamber shown in Fig. 1, a. At nitrogen pressure 0.1…0.3 Torr the discharge burns only in the abnormal mode. Starting from the pressure of 0.5 Torr and above with low discharge current values the discharge spot occupies only a part of the cathode surface, and a normal mode is observed which experiences to the abnormal one with current increasing. Decrease in the anode diameter led to the increase of the minimum voltage of discharge sustainment. CVCs of the discharges in argon registered in the discharge chamber shown in Fig. 1, b demonstrated a similar behavior.

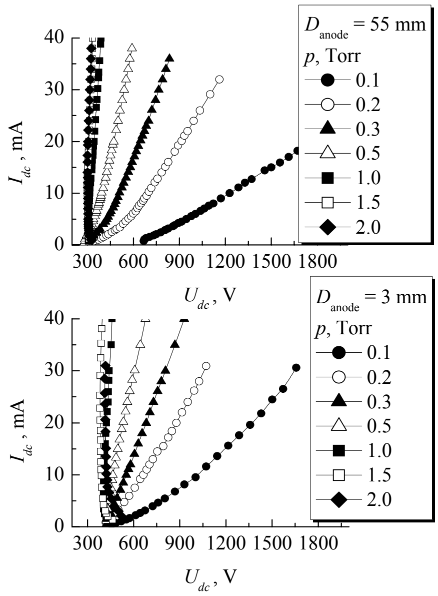

Fig. 4. Current-voltage characteristics of glow discharge at different nitrogen pressure values with anode diameters of 55 mm (a) and 3 mm (b). Tube diameter is 55 mm

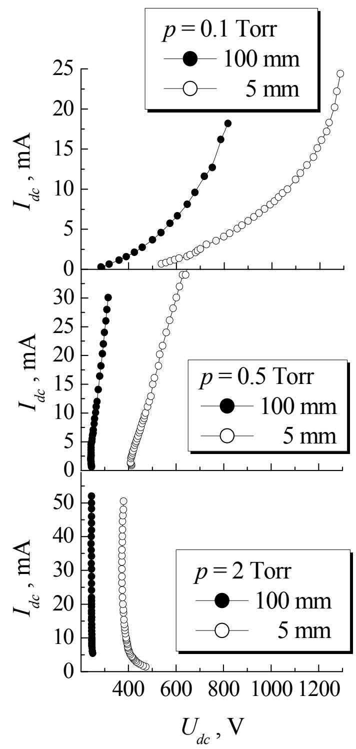

Fig. 5. Current-voltage characteristics of glow discharge in argon at pressures of 0.1, 0.5,and 2 Torr and anode diameters of 100 and 5 mm. Tube diameter is 100 mm

Fig. 5 compares CVCs of the discharge in argon registered at identical gas pressure values and different anode diameter values. It is clear from the figure that at $p = 0.1$ Torr CVCs for the anode diameters of 100 mm and 5 mm are similar qualitatively but the decrease in anode diameter led to the increase in the discharge extinction voltage. For the pressure $p = 0.5$ Torr at the smallest discharge currents we observe the normal mode of burning, that is the discharge spot occupies only a part of the cathode surface. At $p = 2$ Torr in a broad range of current values the discharge burns in the normal mode for the small as well as big anodes. However for the anode of 5 mm in diameter the discharge current lowering is accompanied by a substantial increase of voltage across the electrodes. For the anode of 100 mm in anode this effect is pronounced more weakly. Usually the discharge column in the normal mode burning between the electrodes of large area occupies larger area on the anode than on the cathode. But with the anode diameter of 5 mm the situation is the reverse, i.e. the discharge column on the anode is limited by its area and it cannot expand but near the cathode the column expands. In the case of electrodes of large area the expansion of the plasma column near the anode is due to ambipolar diffusion of charges particles. And for the compensation of electron losses from the discharge column of small diameter the voltage across the electrodes must be higher. In the case of a small diameter anode the discharge column narrowing accompanying electron motion to the anode leads to their enhanced escape due to ambipolar diffusion. This circumstance may explain the considerable growth of voltage across electrodes when the current of the normal mode of the glow discharge with a small anode lowers.

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ВЛИЯНИЕ ДИАМЕТРА АНОДА НА ЗАЖИГАНИЕ И ГОРЕНИЕ РАЗРЯДА ПОСТОЯННОГО ТОКА

В. Лисовский, Е. Скубенко, Е. Кравченко, В. Егоренков

Исследовано влияние диаметра анода на зажигание и вольт-амперные характеристики тлеющего разряда постоянного тока. Уменьшение диаметра анода приводит к смещению кривых зажигания в область более высоких давлений газа и пробойных напряжений, а также повышает напряжение угасания разряда. В нормальном режиме горения для небольших анодов уменьшение разрядного тока сопровождается значительным повышением напряжения на электродах. Вблизи малого анода наблюдается яркое анодное свечение во всем исследованном диапазоне давлений газа.

ВПЛИВ ДІАМЕТРА АНОДУ НА ЗАПАЛЮВАННЯ ТА ГОРІННЯ РОЗРЯДУ ПОСТІЙНОГО СТРУМУ

В. Лісовський, К. Скубенко, К. Кравченко, В. Єгоренков

Досліджено вплив діаметра аноду на запалювання та вольт-амперні характеристики тліючого розряду постійного струму. Зменшення діаметра аноду призводить до зсуву кривих запалювання в область більш високого тиску газу і пробійних напруг, а також збільшує напругу згасання розряду. У нормальному режимі горіння для невеликих анодів зменшення розрядного струму супроводжується значним збільшенням напруги на електродах. Поблизу малого аноду спостерігається яскраве анодне світіння у всьому дослідженому діапазоні тиску газу.