NANOSECOND DISCHARGE IN AIR IN SUBMILLIMETER GAPS IN A UNIFORM ELECTRIC FIELD*

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A pulsed nanosecond discharge in air at atmospheric pressure in a uniform electric field in the region of 10^6 V/cm is under investigation. The cathode-anode gap length reached fractions of a millimeter, and the gas pressure was atmospheric. Under such conditions, electrons runaway (RE) during the discharge. Such a discharge is referred to as nanosecond diffuse-channel (NDC). In such discharges, the critical length of the electron avalanche x_k is much smaller than the gap length, i.e., $x_k \ll d$. The greatest attention is paid to the discharge at d = 0.1 mm, when the overvoltage across the gap was 15. Due to careful processing of the cathode surface, one-electron discharge initiation was achieved. The initiating electron enters the discharge gap and ionizes air molecules due to REs.

During the discharge formation time of about 10^{-9} s, plasma accumulates. Upon reaching the critical value of the plasma density of the order of $n_k=10^4$ cm^3, a glow discharge (GD) begins. It leads to redistribution of the electric field to the plasma column and the cathode layer (CL). This redistribution lasts for a short time of the order of 10^{-11} s, which is called the commutation time. This beam occurs due to a rapid increase in the plasma density during the discharge. During this time, a beam of runaway electrons is formed in the number of $5\cdot10^{10}$ pieces, which, falling on the anode, leads to the formation of an X-ray pulse. Let us assume that the reduced electric field E_T/p in the CL obeys the scaling law and depends on j/p^2, where j is the current density at the cathode and p is the gas pressure. For a rough estimate, we use the formula

$$E_T / p = 1.1\ 10^5 \left(j / p^2 \right)^{0.6} \tag{1}$$

for nitrogen. It was obtained experimentally in the study of many discharges in the GD mode. For the used gap d=0.1 mm, the discharge current is equal to i=280 A, and the cathode surface area is $S=\pi D^2/4$=0.2 cm^2, where D is the cathode surface diameter. It is difficult to accurately determine the current density j, since it is not known what part of the cathode it occupies. If it occupies the entire surface, then $E_T=10^6$ V/cm, and if it takes only 10%, then $E_T=3.4\cdot10^6$ V/cm. It is known that when the electric field on the cathode is 10^6 V/cm or more, field emission (FE) from microprotrusions on the cathode surface takes place. Under the action of the FE current, an electric explosion of these microprotrusions occurs, which initiates a transition to explosive electron emission. This leads to the formation of explosive electron emission and the formation of a cathode spot and the transition of the discharge to the arc mode.

It should be noted that in the electric discharge in air we have considered, there are two types of runaway electrons. The first one is when runaway electrons participate in the process of discharge formation. The duration of this process with one-electron initiation is ~10^{-9} s. The second type is runaway electrons in the final stage of the discharge. They appear in the form of a beam with a duration of ~10^{-11} s with the number of electrons $5\cdot10^{10}$.

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