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THE FEATURES OF BREAKDOWN OF HIGH-VOLTAGE NANOSECOND DISCHARGE INITIATED WITH RUNAWAY ELECTRONS IN A NONUNIFORM ELECTRIC FIELD [1]

*M.I. LOMAEV**,**, *D.V. BELOPLOTOV**,**, *D.A. SOROKIN* *, *V.F. TARASENKO**,**

**Institute of High Current Electronics, 2/3 Akademichesky Ave., Tomsk, 634055, Russia, VFT@loi.hcei.tsc.ru, phone: +7 3822 491685*

***National Research Tomsk State University, 36 Lenin Ave., Tomsk, 634050, Russia*

Currently, increased attention is paid to the pulse and pulse-periodic discharges in the dense gases initiated with runaway electrons under conditions of an inhomogeneous electric field distribution. The main feature of such discharges is a generation in a gap of runaway electrons and X-ray, affected on a breakdown. These processes was shown in [1-4] to provide the formation of diffuse discharges at the excitation of gas medium by high-voltage nanosecond pulses of both polarities. The increased interest in the study of runaway electron preionized diffuse discharge (REP DD) is due to the presence of a number of unresolved fundamental problems in this area of gas discharge physics. Among them are the process of the breakdown and discharge formation, refinement the mechanism of generation of runaway electrons and others, as well as opportunities of wide practical application of the high-pressure non-equilibrium low-temperature plasma, in particular, for cleaning, oxidation and hardening of metal surfaces [4].

The objective of this work is to study the initial phase of a breakdown in an inhomogeneous electric field in the gases at pressure of 0.013-0.7 MPa during the REP DD formation.

Investigation of breakdown was carried out by means of registration of waveforms of discharge plasma radiation intensity from different areas along of the longitudinal axis of discharge gap, voltage pulses and current through the gap. Discharge chamber with a strong nonuniform distribution of electric field intensity was filled with pure nitrogen (N_2) or mixture of sulfur hexafluoride (SF_6) with 2.5% N_2 admixture. The voltage pulse produced with the RADAN-220 pulser was applied through a short transmission line to an electrode with small radius of curvature. The spatial and time resolution of the registration system of radiation was ~1 mm and 100 ps, respectively. The duration of breakdown stage depending on the gas pressure can vary from tens to several hundred picoseconds. Therefore, high-pressure gases were used to increase the breakdown stage duration and decrease the effective lifetime of the $C^3\Pi_u$ state. It permitted to obtain more accurate information about the time evolution of radiation intensity from different discharge gap areas.

Experiments were carried out at the nitrogen pressure of 0.013-0.7 MPa, as well as in mixture of SF_6 with 2.5% N_2 at the pressure of 0.013-0.25 MPa. Delay of start of the radiation from the different areas along of the longitudinal axis of discharge gap relative to the onset of voltage pulse was found to be the function of a nitrogen/mixture pressure, time and distance from the potential electrode, as well.

The analysis of experimental data was based on equations, describing the relation between experimental data and values that depend on the local electric field strength. It was concluded, that the high-voltage breakdown of the gap with a nonuniform electric field distribution at elevated gas pressures and subnanosecond rise time of voltage pulse is occurred owing to the ionization wave characterized by amplification of the electric field strength in the area of its front. The average velocity of ionization wave is ~$(2.1\text{-}6.5)\cdot 10^7$ m/s in mixture of SF_6 with 2.5% N_2 admixture at pressures of 0.05-0.25 MPa and ~$(0.5\text{-}1.3)$ 10^8 m/s at nitrogen pressures of 0.1-0.3 MPa at negative polarity of electrode with small radius of curvature Practically simultaneous increasing of the radiation intensity in areas near the grounded electrode is observed. This fact indicates to the possibility of changing the breakdown mechanism in this part of the discharge gap.

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