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HIGH VOLTAGE NANOSECOND DISCHARGES IN AIR AT NONUNIFORM CONFIGURATION OF ELECTRIC FIELD

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Abstract- High voltage nanosecond diffuse discharges in a nonuniform electric field are studied experimentally using a recording system. Formation of "runaway" electrons in gases and (formation) the powerful electron beams on the discharge gap are considered. At atmospheric pressure X-ray radiation from discharge gap during the high voltage nanosecond breakdown has been fixed. It is shown that X-ray radiation at the discharge is initiated by "runaway" electrons.

Keywords: NanoSecond Discharge, Nonuniform, Field.

I. INTRODUCTION

It has been known that at atmospheric pressure a diffuse discharge in different gases can be initiated [1, 2]. To this end, short high voltage pulses and a discharge gap the cathode of which has a small radius of curvature should be applied in non-uniform electrical field at the atmospheric conditions. Under the influence of high voltage nanosecond pulses the high specific energy up to 1J/cm^3 and electron beams by record current amplitude were received. Space structure of discharge gap's glow during the pulsed discharge process is defined by some factors such as the electrodes geometry, pressure and type of gas, inductive and capacitive parameters of generator, and breakdown voltage of discharger-peaker [9]. These discharges are known to generate X-rays [1, 2] and runaway electron beams [3]. Nevertheless, they remain poorly studied, because it is difficult to measure their parameters and also the parameters of attendant runaway electron beams and subnanosecond X-ray pulses [4, 13, 14, 15].

II. EXPERIMENTAL RESULTS AND DISCUSSION

Experimental researches have been spent on a discharge gap at atmospheric pressure. For initiation of the nanosecond pulse discharge the generator of high voltage impulses under the Arkadyev-Marks scheme was used. In Figure 1(a) the block scheme of an experimental installation is shown. Impulse voltage was supplied from generator 1 to high voltage electrode-cathode 3 inside the chamber 2 at atmospheric pressure of air - P=760 Torr. Two cathodes by different curvature radius - r_c ~ 1 and 6 mm were used. As an anode the copperplate 4 and metal netting 5 were used. Interelectrode distance ~d was changed over the range ~ 3-10 mm.

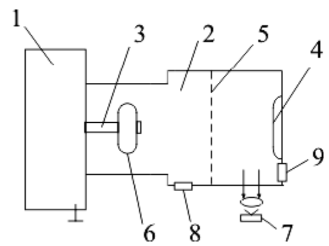


Figure 1. Block scheme of an experimental assembly
1- high voltage nanosecond generator, 2- vacuum chamber, 3- cathode, 4- anode, 5- metal netting, 6- fluoroplastic cap, 7- electron-optical camera, 8- shunt for measuring of discharge total current, 9- shunt for measuring of electron beam's current

For photographing of the high speed pulsed discharge glow an electron-optical camera CCD was used. The total current of pulsed discharge was registered by high-frequency oscillograph TDS-5104 by means of current shunt. Sideways from a discharge zone at distance of 5cm the DP5V dosimeter for registration of x-ray radiation dose of nanosecond pulse discharge has been located. Opposite to it the cartridge with a X-ray film of CP-BU New mark was established

On a generator's output the high voltage impulse by amplitude of U=60 kV, duration of 200 ns and front of 20 ns is formed (Figure 2). Measurements were carried out only after the trainings of electrodes surface by series of discharge pulses. At feeding of 10 mm discharge gap by nanosecond impulses of voltage diffuse discharge was formed. Figure 3 shows the discharge photo.

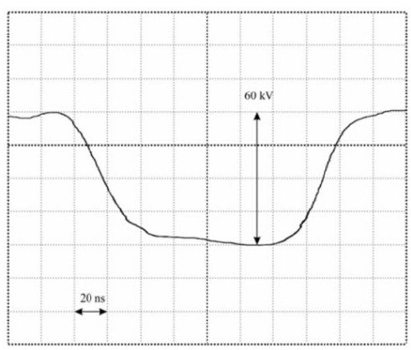


Figure 2. Oscillogram of high voltage pulse

Figure 3. Discharge photo. r_c= 6 mm, anode - copperplate, U=60 kV, P=760 Torr, interelectrode distance d=10 mm

It is shown in Figure 3, that at atmosphere pressure, U=60 kV and d=10 mm the diffusive volumetric discharge is realized. The discharge had the form of a cone with close discharge streams at the basis. The given discharge form was fixed by cameras for one impulse. At voltage reduction to 40 kV near the cathode in the dark the weak diffuse luminescence was visually observed which was not registered by cameras even for tens impulses.

In Figure 4 the oscillogram of discharge current is presented. The current in the discharge gap of 10 mm length at voltage 60 kV and cathode radius of curvature 6 mm was equal 0.4 A. The cathode and cathode plasma are the sources of runaway electrons in air at atmosphere pressure. Dispersion on gas molecules strongly influences on the space distribution of runaway electrons. In case of pointed cathode the interelectrode distance – d greatly influences on the width of runaway electrons beam. As the analysis is shown at increase the - d up to 10 mm beam's diameter reaches to Φ~3 cm. The streams structure respond to distribution of cathode emitting centers. Plasma bunch on cathode is transformed into constricted channel growing deep into discharge gap by the stream of runaway electrons.

Variety of discharges space forms is explained by statistic of this interaction and by statistic of electron avalanches initiation. When overvoltage factor $\Delta >> 1$, the gas breakdown is initiated by auto electronic emission and the first avalanche reaches a critical size near the initialization point (Z_{cr}~ 100 μ << d).

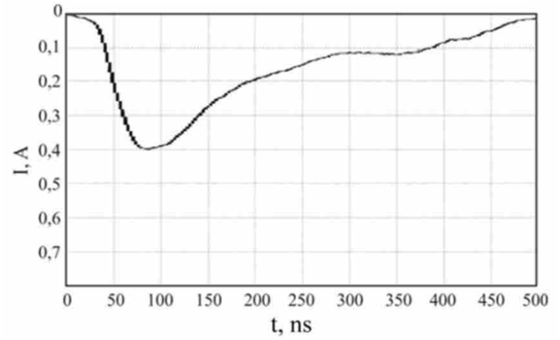
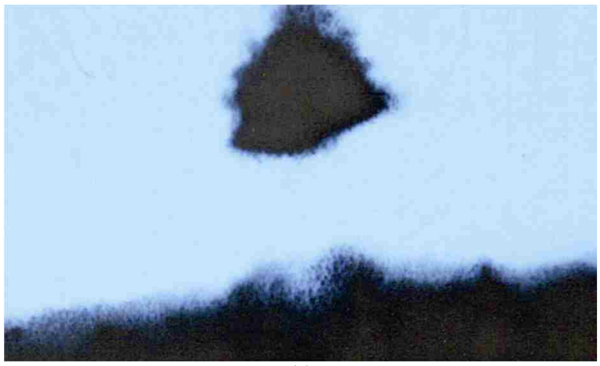


Figure 4. Oscillogram of current pulse

As a result the strengthening of positive space charge field E_{p+} and auto electronic emission are taking place. Therefore, when $\Delta >> 1$, the emissive processes play a fundamental role in propagation of ionization towards the cathode. The high penetrability of runaway electrons and X-ray radiation lead to ionization of gas far off the first ionization centers and discharge loses its compact form acquiring the diffusive or multi-channel character. The space structure of discharge gap's glow, as mentioned above, is determined by some parameters such as electrodes geometry, interelectrode distance - d, gas pressure - p and parameters of generator.

It is known that the discharge plasma is a source of X-rays, runaway electron beams, and optical radiation in different spectral ranges [4-12]. In this work, we also detected X-ray radiation and an ultrashort avalanche electron beam behind the anode and the discharge plasma was a source of powerful spontaneous radiation. For the generator, the maximal amplitude of the beam current behind the 20 µm thick copper netting was about 27 A for a 10 mm wide gap.

In Figure 5 the X-ray radiation photography is presented. As we can see from Figure 5(a), the high intensity of X-ray radiation from discharge gap takes place. The exposure dose of the X-ray radiation near the anode was 0.6 mR. These parameters of the electron beam and X-ray radiation were obtained for voltage pulse duration of 200 ns. As the voltage pulse shrank to 100 ns or less, the amplitude of the runaway electron beam current, the exposure dose of the X-ray radiation, and the energy of runaway electrons decreased (Figure 5(b)).



(a)

(b)

Figure 5. Photography of X-ray radiation from discharge gap

III. CONCLUSIONS

We studied the breakdown of gaps with a nonuniform electric field distribution in atmosphere of air. Breakdown was initiated by applying high voltage pulses with duration of 200 ns or less. The shrinkage of the voltage pulse extends the conditions for diffuse discharge initiation without preionization. The volume discharge is initiated owing to the preionization of the gap by runaway electrons and X-ray photons. When the electrode with a small radius of curvature is under a negative potential, the formation of a diffuse discharge is due to preionization by runaway electrons, which are generated in the discharge gap because the field enhancement near the cathode and in the gap.

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BIOGRAPHIES

Arif M. Hashimov was born in Shahbuz, Nakhchivan, Azerbaijan on September 28, 1949. He is a Professor of Power Engineering (1993); Chief Editor of Scientific Journal of "Power Engineering Problems" from 2000; Director of Institute of Physics of Azerbaijan National Academy of Sciences (Baku, Azerbaijan) from 2002 up to 2009; and Academician and the First Vice-President of Azerbaijan National Academy of Sciences from 2007. He is laureate of Azerbaijan State Prize (1978); Honored Scientist of Azerbaijan (2005); Cochairman of International Conferences on "Technical and Physical Problems of Power Engineering" (ICTPE) and Editor in Chief of International Conferences on "Technical and Physical Problems of Engineering" (IJTPE). His research areas are theory of non-linear electrical chains with distributed parameters, neutral earthing and ferroresonant processes, alternative energy sources, high voltage physics and techniques, electrical physics. His publications are 280 articles and patents and 5 monographs.

Rauf N. Mehdizadeh was born in Baku, Azerbaijan, 1943. In 1967 he graduated from Moscow Power Engineering Institute, Moscow, Russia. Since 1967 he works in the Institute of Physics of Azerbaijan National Academy of Sciences, Baku, Azerbaijan in High Voltage Physics and Technology Laboratory. In 1981 he honored by Ph.D. degree and from 2010 he is a Doctor of Technical Sciences. He is the editor of scientific journal "Power Engineering Problems" and Secretary of International Conferences "Technical and Physical Problems of Power Engineering" (ICTPE). He published about 120 published proceedings in journals of the CIS countries, the USA, Germany, Bulgaria, the United Arab Emirates, Turkey, Iran, 15 patents, reports and appearances at many international conferences.