HIGH VOLTAGE PULSED DISCHARGE IN AIR IN ATMOSPHERE PRESSURE AND THE BIG OVERVOLTAGES

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ABSTRACT

Present article is devoted to the discharge processes in air by influence of high voltage nanosecond pulses on the discharge gap. Are considered a local and non-local measures of run off electrons and formation of the powerful subnanosecond electron beams. Are shown the conversion of diffusive volumetrical discharge into constricted discharge by different interelectrode distances and electrode's geometry.

Keywords: discharge, influence, high voltage nanosecond pulses, subnanosecond, electron beams.

I. INTRODUCTION

Study of the nanosecond pulsed discharge in gases in atmosphere pressure is presenting a big interest. Both in gases and condensed mediums the main mechanism of this process is connected with run off electrons effect [1]. Run off electrons phenomenon in plazma is known a long time ago, were done numerical computations and analytic treatment for low fields. This phenomenon has a vital importance for diagnostics and energy-balance of admixtures in plazma of tokamaks [2].

II. EXPERIMENTAL METHODS

Run off electrons phenomenon is observed in gases, formation mechanism in gas takes on special significance in view of getting electron beams with record big current amplitude in air in atmosphere pressure ~70*A* [3]. Depending on overvoltage level and interelectrode distances is realized both the local and non-local mechanisms in breakdown discharge process in gas in atmosphere pressure.

By the low overvoltages level (Δ<<1) the breakdown discharge is a local at the point of the space of time (r,t) and is determined by local field at the same point like $E(r,t) = E_o + E_p(r,t)$, where E_o and $E_p = E_{p+} + E_{p-}$ - external field and space charge's intensities. Is taken place Townsend's avalanche generation with γ-processes on cathode and formation of streamers by using that we can describe the ionization processes in solid gases. These processes correspond to right part of Pashen's curve ($pd >> (pd)_{min}$), where the space charge Z_{cr} and time t_{cr} avalanche progress scales satisfy to correlation:

$$Z_{cr} = \alpha^{-1} \cdot ln N_e^{cr} \le d$$

$$t_{cr} \le \frac{d}{\upsilon_-}$$

where N_E^{cr} - electrons quantity on the critical avalanche, *d*- interelectrode distance.

By the big overvoltages level (Δ>>1) the whole of gas-discharge process development differs from classical discharge form. With growth of overvoltages the scales of Z_{cr} and t_{cr} are sharp decreased and electrons ordered motion is compared with whole kinetic energy. At that on the streamer's front can be generated the run off electrons when $E_o < E_{cr}$, where E_{cr} – critical field intensity, that provides the continuous acceleration of electrons. Beginning from the some big intensity E_o is happened the field displacement on the streamer's front as a result of it's polarization and synchronous motion of the growing boundary field and accelerating electrons.

The run off electrons supply the big speed of ionization field propagation to the anode and the prior ionization of gas by attendant X-ray emission excites a photoelectric effect on the cathode and determines the streamer's motion, directed to the cathode. The cathode and cathode plazma are the sources of run off electrons in air in atmosphere pressure. Dispersion on molecules strongly influents on the space distribution of run off electrons. In case of pointed cathode, the interelectrode distance – *d* greatly influents on the width of run off electrons beams. By increase of - *d* up to 15 mm the beam's diameter reaches ∅~3*cm.* If there are some channels in discharge that take place on developed work surface, the channel's quantity are equal to beam's quantity in electron stream behind the anode. The stream structure responds to emitting centers distribution on the cathode. The plazma bunch on the cathode is transformed into constricted channel that growth deep into discharge gap by run off electron's stream. Though the reached power density input in discharge gap is ~100 MVt/cm^3, but plazma is low-temperature, weakly ionizated at the all discharge's development stages because there is the weak coupling of run off electrons with gas. Statistics of this interaction and fulmination of electron avalanche is explained by variety of discharge space forms.

When Δ>>1, the air breakdown is initiated by autoelectronic emission and the first avalanche becomes a critical size near the initialization point (d >> Zcr ~ 100 mcm).

As a result is happened the field strengthening of positive space charge Ep and autoelectronic emission. Therefore, when $\Delta >> 1$, the emissive processes play a fundamental role in ionization propagation towards cathode.

The high penetrability of run off electrons and X-ray emission reduces to air ionization far off the first ionization center and discharge loses it's compact form and takes diffusive or multi-channel character.

By big overvoltages in air in atmosphere pressure the complex space structure of the nanosecond volumetrical discharges as the constricted channels is explained by electron's acceleration in space charge field and are permitted to accelerate up to anode.

These electrons radiate the quantums ionizing the gas in whole discharge gap and battered even the electrons from electrodes.

The space structure of the discharge gap glow is determined by parameters such as electrode's geometry, interelectrode distance – *d*, gas pressure, generator's parameters.

The photography of the discharge gap glow in air for different values of interelectrode distance – *d* and cathode's geometry are presented on figures 1-4.

As the anode is flat copperplate and the metal screen, but the cathode are iron core by different radiuses of curvature – r_k.

On (figure 1) in atmosphere pressure, U_{gen}= 60 *kV* and *d*=15 *mm* is realized the diffusive volumetrical discharge.

Figure 1
r_k=6 mm, anode - copperplate,
U_{gen}=60 kV, P=760 Torr,
interelectrode distance d=15 mm

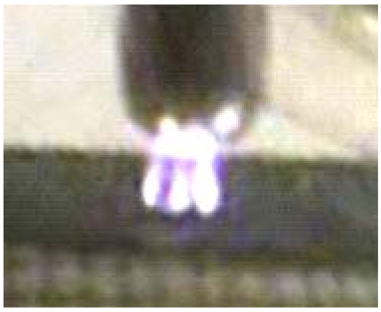

Figure 2
r_k=6 mm, anode - copperplate,
U_{gen}=60 kV, P=760 Torr,
interelectrode distance d=5 mm

On the cathode is formed the plasma bunches by visible dimension l_p ~ 2 *mm*<< *d*, but remaining space up to anode is filled up by diffusive glow.

The cathode plazma generations significantly are not uniform.

On (figure 2) is shown that in atmosphere pressure and interelectrode distance – *d*=5 *mm* there are some plazma bunches on the cathode field and is realized the conversion from diffusive volumetrical discharge to constricted discharge at that the constricted channels quantity is equal bunches ones on the cathode

We have to note, when we decrease the air pressure, the. bunche's dimension on the cathode is increased and luminosity is decreased.

When *P<0.5 Torr* the discharge phenomena on the case of planar electrodes with developed work surface aren't observed, but if cathode is a iron core by different radiuses of curvature, the plazma bunches are observed on it's surface and theirs size is significantly smaller in comparison with *P*=760 *Torr.*

On (figure 3) when the cathode's radius of curvature is decreased up to r_κ *~1mm,* the interelectrode distance *d*=10 *mm,* U_{gen}= 60 *kV* and *P*=760 *Torr,* the bright constricted channel's intergrowth and whole discharge gap overlap is observed.

Figure 3
r_k= 1 mm, anode - metal screen,
U_{gen}=60 kV, P=760 Torr,
interelectrode distance d=10 mm

Figure 4
r_k= 1 mm, anode - metal screen,
U_{gen}=60 kV, P=760 Torr,
interelectrode distance d=3 mm

On (figure 4) by decrease of the interelectrode distance up to d=3 *mm* the enlargement of discharge channel is happened. Diffusive cover in that case is not observed.

In case of sharply nonuniform field is fixed only one bright channel and bunch. By increase of the field uniformity the channel's and plazma bunche's quantity is grown.

By multiple overvoltages in volumetrical discharges in air the ionization emission reaches the velocity of light and current pulse with the high rate of pulse rise ~ 10 *TA/s* is realized.
In that case the front duration of pulse is τ_I <0,5ns and upper bound of current is I_m ~1,5 kA.

By decrease of the interelectrode distance – d the volumetrical discharges pass into constricted channel and the current amplitude I_m and channel's conductivity is grown.

Also we have to note the importance of the breakdown delay interval parameter – t_d relatively to moment of application of voltage pulse that characterizes the speed of ionization processes development.

When d < 15 *mm* and U_{gen} > 180 *kV* independently from cathode geometry in air in atmosphere pressure the big conduction current is already appeared on the front of voltage pulse and $t_d < \tau_I < \tau_{gen} < 0{,}6$ *ns,* where τ_I is an acceleration time of voltage pulse at the discharge gap.
So speed of ionization propagation $V_I > d/t_d > d/\tau_{gen} > 2.5\cdot10^9$ *cm/s* is more than speed of streamer's propagation. When U_{gen}< 180 *kV* in relatively uniform field we can register breakdown delay interval parameter – t_d ~2 *ns* for cathode's radius of curvature r_c ~20 *mm*.By decrease of pressure this parameter t_d is grown.

III. CONCLUSION

Thus in this article is shown that by big overvoltages Δ>>*1* in air in atmosphere pressure the presence of high energy electrons reduces to formation of powerful subnanosecond electron beams and has a fundamental role in breakdown mechanism and in all pulsed discharge dynamics in solid gases.
Particular interest for physics and technics of high voltage and high pressure dischargers presents an advance of acceleration processes researches to high pressure area more than atmosphere pressure. These processes are effective in initialization systems and for pumping of high pressure lasers.

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