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A NEW METHOD OF HIGH VOLTAGE SUPPLY TO STREAMER CHAMBERS

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Results are presented of theoretical calculations and experiments which were carried out with the aim of obtaining bright and narrow charged-particle tracks in a streamer chamber by applying a number of pulses of alternating polarity. Tracks are obtained which have almost the same size and brightness of the luminous centers ($\delta = 1-2$ mm) in the directions along and perpendicular to the electric field. The experimental results are in satisfactory agreement with the calculations. It is shown that the new method of high voltage power supply yields high quality tracks more consistently than when single high voltage pulses are applied to the chamber plates.

AT the present time the streamer chamber (track spark chamer), first proposed by Soviet scientists,[1,2] is finding more and more application for detection of high-energy particles. Its advantage is the greater isotropy, compared to spark chambers, in the recording of particle tracks, and its disadvantage is the low brightness of the track, which makes photography of the tracks difficult, and also instability of operation of the chamber as the result of variation of the pulse length from event to event.

We have developed and verified experimentally[3] a new method of high voltage supply to streamer chambers which permits obtaining narrow, bright tracks with good stability.

1. THEORETICAL PREMISES

The brightness of an electrical discharge in a gas is directly proportional to the number of excitation, ionization, and recombination events.[4,5] In application to the streamer chamber, the problem of increasing the track luminosity can be formulated in the following way: it is necessary to increase the number of ionizations in each individual streamer without substantial increase of the spatial dimensions of the ionized region. This can be achieved if, after the action of the main pulse on the chamber, we apply an oscillatory voltage or a series of pulses of alternating sign, as has been suggested by G. A. Vorob'ev (private communication).

The picture of the ionization processes in the chamber with the proposed means of voltage supply is as follows.

Let the first pulse have such an amplitude and length that the shower initiated from one primary electron develops to the critical stage, but does not yet transfer to a streamer (Fig. 1a). The electrons arising in the front of the discharge lead the plasma cloud of positive ions and a small number of electrons by an amount $1/\alpha$[6] (α is the first Townsend coefficient) and as a result an internal electric field is created. When the external field begins to change sign, these electrons, under the action of the internal field, enter the plasma cloud.

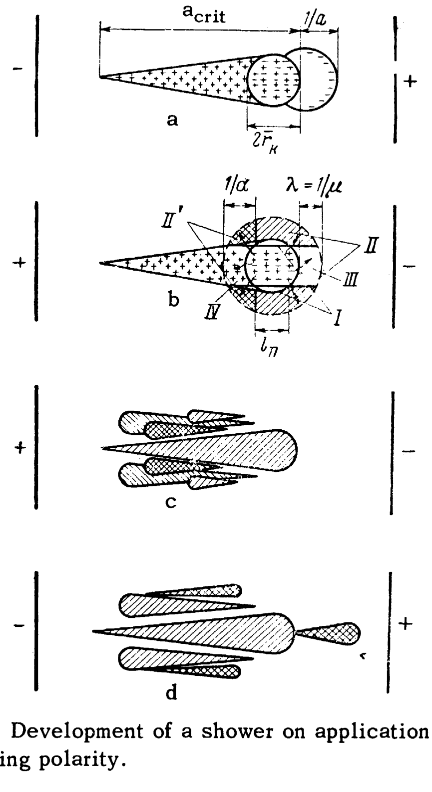

FIG. 1. Development of a shower on application of pulses of alternating polarity.

Inside the cloud, electron-ion recombination processes will occur with emission of photons which will be absorbed by the gas. As a consequence of this, a layer of photoelectrons of thickness $1/\mu$ will be formed around the head of the shower (μ is the absorption coefficient of the photons). After the field changes direction, formation of a second shower begins, which moves in the opposite direction to the first.

Figure 1b shows the different regions of ionized space. Region I is a cylinder cut from the head of the first shower; the cross section of this cylinder is a section with a base l_D (the Debye length[6]). From this region, and also from region II where the density of photoelectrons and positive ions is small, electrons can be removed by the external field and produce impact ionization. The photoelectrons formed in region III will be driven by the external field into the head of the first shower and will not be able to participate in formation of the second shower. The external field also cannot remove photoelectrons from region IV, as a consequence of the high ion density.

Calculations give a quantity of initial electrons for the second shower of the order of 20. If the second pulse is the same as the first, the second shower will reach critical dimensions earlier than the first, and subsequently a streamer will develop which, as a consequence of the high velocity, can lead to the projection regime in the chamber. In order to avoid this, it is necessary to decrease the second pulse with respect to the first in amplitude or duration. Figure 1c shows the development of the second shower, inside which is located the first shower. Since photons are continuously emitted from the head of the first shower, after the main shower will follow successive showers which, merging into the positive space charge left by the main shower, cut short their development. However, the succeeding showers, reducing the field produced by the positive charge left by the main shower, accelerate somewhat the development of the latter. These succeeding showers are also shown in Fig. 1c. The considerations in calculation of the number of initial electrons for the succeeding showers are the same as those for the second shower. However, it must be taken into account that in the action of the third, fourth, and subsequent pulses, in addition to the formation of the showers developing parallel to the axis of the first shower and increasing the brightness of the track and providing good localization of the light, showers will develop from the heads of the preceding showers (Fig. 1d), which are undesirable because of the extension of the luminous region in the form of a halo of lesser brightness.

A calculation showed that the effect of ambipolar diffusion of positive ions and electrons on the change of the luminous region during the time being considered is unimportant.

On the basis of the calculations carried out we can draw the conclusion that, supplying to the chamber plates a definite number of oscillations, we can obtain a bright track with good localization of the light.

2. EXPERIMENTAL RESULTS AND DISCUSSION

Experimental verification of the calculations was carried out in a streamer chamber consisting of three glass cases 160 × 100 × 600 mm, cemented together with epoxy resin and filled with neon to a pressure $p = 750$ mm Hg. The distance between the electrode plates of the chamber was 150 mm. A pulse was fed to the plates from a generator[7] which permitted us to obtain pulses of double amplitude on the plates up to 500 kV (unmatched loading) and with a rise time of 1.5×10^{-9} sec. The generator was triggered by a coincidence circuit which received pulses from two rows of counters forming a telescope. The delay time of appearance of the first pulse on the plates after passage of a charged particle through the chamber was $\sim 1\ \mu$sec.

In front of the chamber a cutoff spark gap was set up in an atmosphere of nitrogen at $p = 10$ atm, which permitted smooth control of the duration of the first pulse. Pulses of alternating polarity were obtained after cutting off the first pulse because of the oscillatory discharge of the capacity of the chamber plates through the cutoff spark gap. The period of the oscillations was determined by the capacity of the plates and the inductance of the plate and spark-gap system and amounted to 35 nsec. The number of oscillations depended on the attenuation in the system and was controlled by varying the resistance of the spark in the cutoff spark gap. To obtain a pulse of definite length without succeeding oscillations we used an air cutoff spark gap at $p = 1$ atm, whose spark resistance was greater than in the pressurized spark gap. Photography of the tracks was carried out through a grid electrode (the width of the track transverse to the electric field) and from the side (the width of the track along the electric field) with an f/1.5 objective on Pankhrom-10 film.

Figures 2a, b, and c show photographs of tracks, showing the effect of increasing the number of os-

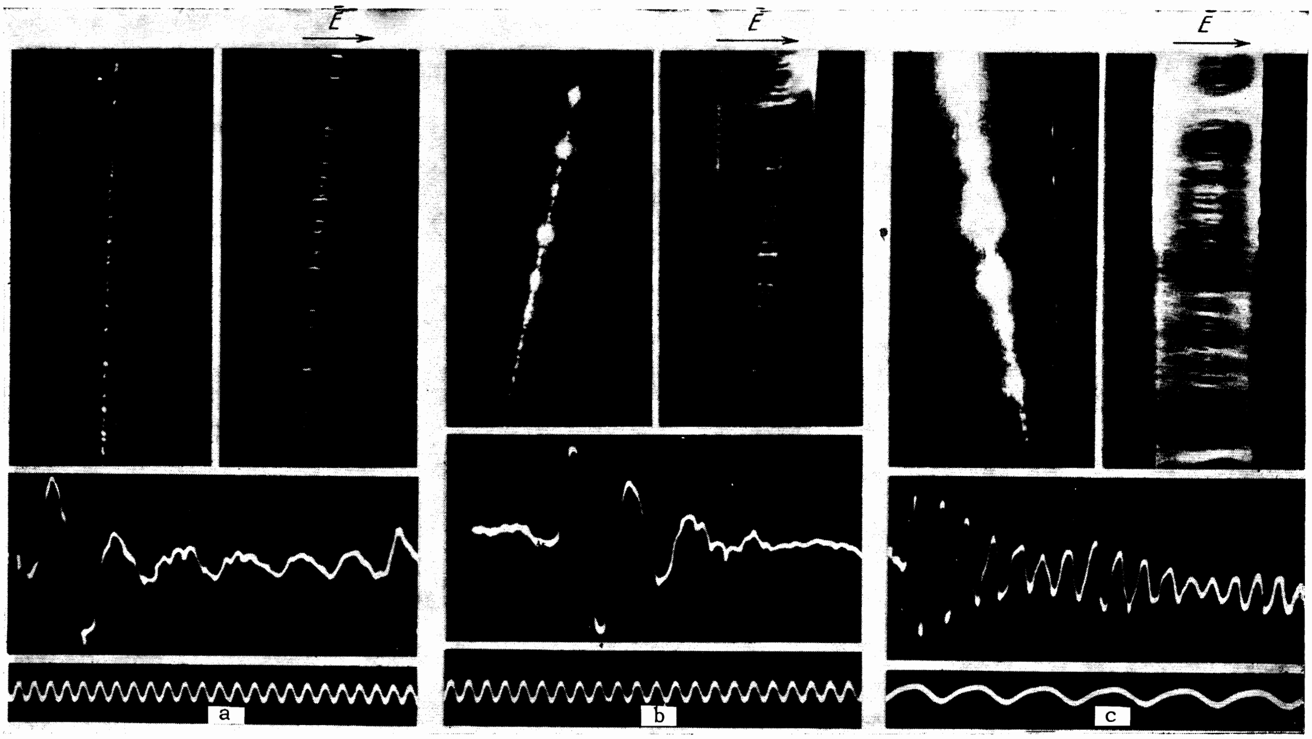

FIG. 2. a, b, c. Effect of number of oscillations on appearance of track. Frequency of calibrating waves: a and b – 100 MHz. c – 10 MHz.

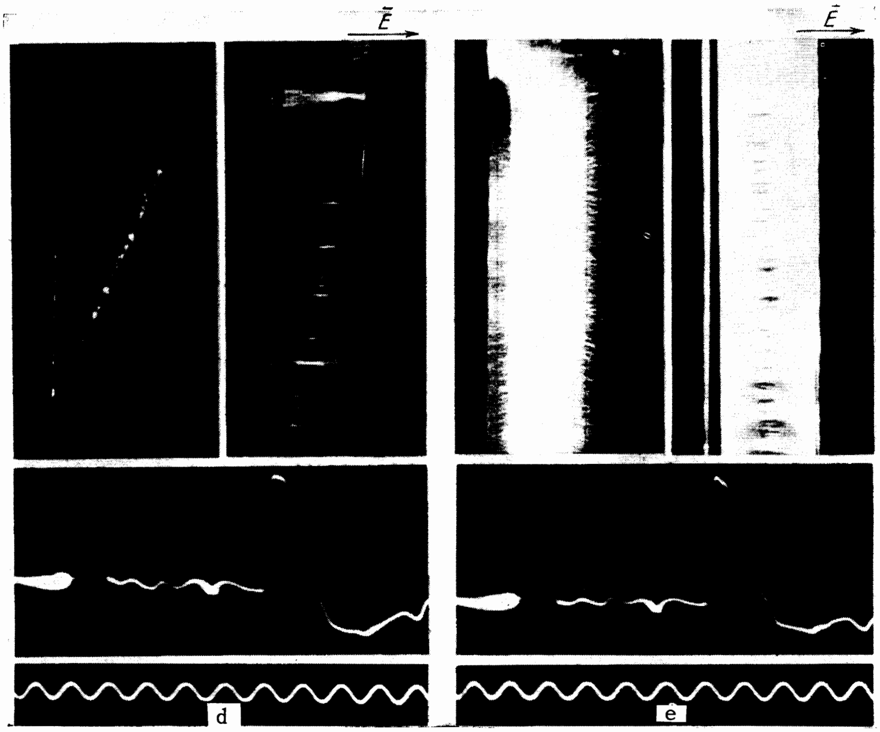

FIG. 2. d and e. Effect of length of a single pulse on track appearance. Frequency of calibrating waves 100 MHz.

cillations on the appearance of the track. Some data supplementing the photographs are given in the table, namely: the electric field intensity E produced in the chamber by the first pulse; the duration of the first pulse τ_1; the total duration of the oscillations making appreciable contribution to increasing the track luminosity T_Σ, and the period of the oscillations T.

For the conditions shown in Fig. 2a, the first three oscillations have an important effect on the

Figure	E, kV/cm					τ_1, nsec	T_Σ, nsec	T, nsec
Fig. 2, a	1 21	2 17	3 7.5	4 3.7	5 3.5	19	54 (First 3 oscillations)	35
Fig. 2, b	21	20.5	13	9.6	6	17	87 (First 5 oscillations)	35
Fig. 2, c	21	20.7	19.5	17	14.5	16	600	35

increase of track brightness, and for the conditions corresponding to Fig. 2b—the first five oscillations. Here the ionization coefficient α is decreased from 245 cm^{-1} for the first pulses to 0.6 cm^{-1} for the fourth and sixth pulses.

The photographs illustrate the gradual transition from the track regime to the projection regime. The satisfactory agreement of the experiments with the theoretical calculations should be noted. In Fig. 2b at the ends of the bright lines (streamers) whose length is ~ 7 mm, a less bright illumination is visible extending to the chamber electrodes, which as we have indicated above is due to the development of additional showers from the heads of the main showers.

With further increase in the number of oscillations a distinct projection regime sets in which is characteristic of this type of high-voltage supply. The entire chamber is filled with a weak illumination in the form of thin filaments (Fig. 2c, side view), but where the particle passed, bright lines are visible whose width is ~ 1 cm. These lines are explained by the fact that here the showers are superimposed on each other, thereby increasing the brightness of the light. Figure 2a shows the track regime of the chamber. From comparison of the front view and side view we can draw the conclusion that we have achieved almost complete isotropy both in the size of the luminous centers and in their brightness in the two directions. The length of the streamers amounts to ~ 1 mm in most cases with individual fluctuations up to 3–4 mm. The fluctuations are due to merging of several showers into one, which consequently develops more rapidly than the others and transfers to a streamer. Figure 2a (side view) exhibits several instances of this sort, where two or three streamers begin to merge with each other. The number of streamers reaches 5–6/cm. Another distinguishing feature of the oscillatory type of chamber supply is the following. The track appearance changes only slightly with a change in the number of oscillations by one or two, while a change of the duration of a single pulse by 1–2 nsec at the same field intensity as in the oscillatory regime leads to a sharp change in track appearance. Figure 2d shows the appearance of the track for a single pulse of duration 13 nsec; the field intensity is 25 kV/cm. The track is distinctly less luminous (side view), although the streamer length is 5–7 mm. Increasing the pulse duration by only 2 nsec leads to the projection regime. Here the track is very bright (cf. Fig. 2e with Fig. 2c).

Thus, when the chamber is supplied by a single pulse high accuracy is required in the time of cutoff of the high-voltage pulse, which has not yet been achieved, and this results in instability of track brightness from event to event.

In the experiments there are certain deviations from the theory. For example, the pulse duration (see the table) is greater than is required by the theory. This is explained by the fact that the pulses are peaked, and not rectangular as in the calculations. Therefore the resulting field intensity, on which the shower development depends, will be less than the maximum value listed in the table.

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