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Abstract

Full Text

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As is known, the plasma of a discharge in long discharge gaps, usually called the positive column, does not always constitute a homogeneous region. Under many conditions the positive column breaks up into luminous layers separated by darker intervals. In such cases the density of charged particles of either sign, the drift velocities of the particles, the electron temperature, and other electrical and kinetic quantities of the plasma have along the discharge axis the same periodic or nearly periodic variation as the brightness of the gas glow.

We investigated the process by which layers stable in space are established in pulsed discharges at pressures of 4.5, 3.8, and 2.8 mm Hg in hydrogen. The discharge vessel was a cylindrical glass tube 3 cm in diameter, provided with two flat electrodes separated from one another by 9 cm. As the power source for the discharge tube, a generator of repetitive microsecond pulses was used. Monitoring of the pulse shape and measurement of its duration were carried out by means of a synchroscope with a special time calibration built into the generator. The pulse had a sufficiently good rectangular shape. The duration of the leading edge of the pulse was 0.1 μsec; the duration was varied from 1 to 10 μsec; the repetition frequency was 100 pulses per second. The amplitude of the current flowing during the pulsed discharge was maintained everywhere equal to 1 A. A considerable time elapsed between pulsed discharges, necessary for the decay of the plasma from the preceding discharge.

By changing the duration of the voltage pulse τ applied to the tube, we could interrupt the process of formation of the stratified positive column at various stages. In this way the sequence of phenomena shown for a pressure of 3.8 mm in Fig. 1 was observed. Taking into account that the exposure time in photographing was 1/20 sec, it should be noted that the photographs yielded an image of the integral picture for 5 completely identical discharges. In Fig. 1a the discharge is shown at the stage ($\tau = 4$ μsec) when it fills the tube with the glow of the cathode region, the Faraday dark space, and the uniform glow of the positive column. For a pulse duration of about 4.5 μsec, on the cathode side of the positive column one can detect one indistinct stable layer (Fig. 1b). As τ is further increased, new layers arise one after another at equal distances from one another. The distance between corresponding points of neighboring layers (the layer length) d_s is equal to 2.7 mm. Although the moments at which individual layers appear cannot be established with great accuracy, since the outlines of the layers emerge and become distinct gradually, nevertheless it can be stated with certainty that their total number increases proportionally to the time elapsed after the appearance of the first layer. The results of the observations gave the following numbers of layers n in the positive column for different pulse durations τ:

τ, μsec	4.5	5	6	7	8	9	10
n	1	2*	3*	4*	4	5	6*

* The last layer on the anode side is indistinct.

We see that, on average, the formation of each subsequent layer requires a time T somewhat greater than 1 μsec. This description applies

and for pressures of 4.5 and 2.8 mm Hg, except that the pulse duration $\tau = \tau_k$ at which, at the beginning of the positive column, the first stable layer is outlined, and also the layer length d_s, have different values for different pressures, as shown by the following data:

p, mm Hg	2.8	3.8	4.5
d_s, mm	4	2.7	2
τ_k, sec	7	4.5	3

The simplest explanation of the observed phenomena may be based on the assumption that the formation of layers stable in space begins after the cathode region approaches the stable state corresponding to the discharge that has developed.

At low pressures the development of a self-sustained discharge is due to the strong growth of electron avalanches in the gas. Oscillographic recording of the development of the discharge under these conditions shows that between the moment at which breakdown begins and the moment at which the breakdown current reaches its steady value, depending on the pressure and kind of gas, the distance between the electrodes, and the magnitude of the overvoltage on the electrodes, a time elapses of the order of from 1 μsec to several tens of microseconds ([1,2]). It is assumed that during this time in the cathode region an accumulation occurs of a space-charge density determining the cathode potential drop, and a plasma is formed that serves to transfer current from the cathode region to the anode. Druyvesteyn points out ([3]) that the transition from a Townsend discharge to a self-sustained high-current discharge is characterized by instabilities and oscillations.

Denoting the statistical lag time by t_1 and the time of passage of the current through the tube by t_2, we have $\tau = t_1 + t_2$. Under the conditions of the experiments t_1 could amount to tens of microseconds, and it may be neglected in comparison with the value of t_2. It should be assumed that the time τ_k is identical with the time of formation of the cathode region with a definite cathode fall suitable for the usual form of a glow discharge. As is seen from the results given above, this time decreases with increasing pressure. We note that an analogous result was obtained earlier for the dependence of the breakdown development time on pressure ([1]). The rate at which the stratification of the positive column takes place can be characterized by the quantity d_s/T, which increases as the pressure decreases, since the layer length d_s then increases; at a pressure of 3.8 mm this rate is approximately $2.7 \cdot 10^5$ cm/sec.

Thus, the experiment presented showed that, during the development of the discharge in time, regular layers fixed in space arise earlier on the cathode side of the positive column, and the stratified state gradually propagates toward the anode with a velocity reaching several thousand meters per second. The results obtained do not contradict Thomson' s theory ([4]), according to which the layers in a discharge represent, in a certain sense, a repetition of the cathode region.

It is necessary to note that, beginning with a pulse duration of about 7–8 μsec, along with the stable layers located on the cathode side of the positive column, trembling layers are observed in all the remaining part. In Fig. 1 the trembling layers appeared in the form of indistinct transverse bands. There is no indication that the appearance of such layers is directly connected with the conditions existing near the cathode.

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Note: Figure translations are in progress. See original paper for figures.