IONIZATION WAVES AND WAKES EXCITED BY AN ACOUSTIC PULSE

V. Krejčí
Institute of Physics, Czechosl. Acad. Sci., Prague*)

Any sudden change of plasma parameters in originally homogeneous positive column of a low current discharge gives usually rise to a transient process, called wave of stratification. Another form of ionization waves, a periodic wake, may be noticed in neighbourhood of a permanent local disturbance of plasma homogeneity. In this work a third form of ionization waves is described, which accompanies a pulse propagating with constant velocity through plasma. After a short description of the experimental techniques a phenomenological theory of the phenomena observed in the resulting diagrams is given.

1. INTRODUCTION

As it is known from many experiments, any pulse disturbance of a glow discharge plasma can provoke under favourable conditions a characteristic process of successive creation of ionization waves, which is called wave of stratification [1]. It develops as result of a chain of ionization and recombination processes, proceeding in time and space together with electric field and electron energy alternations [2]. For studying this phenomenon, usually a short voltage pulse is applied on an external electrode, which causes a local deviation of plasma parameters from the stationary state in the respective region of the positive column, initiating thus the proper stratification process. All sudden changes of plasma parameters usually also cause a wave of stratification starting from the cathode end of the positive column.

Besides of this, permanent inhomogeneities of the discharge path (like tube narrowings or metal probes) give rise to a wave composed of a series of usually damped ionization waves which appear behind the obstacle in the direction to the anode. This phenomenon can also be observed near the cathode region, since the extremities of the positive column act as inhomogeneities of the discharge plasma.

It can be expected that a similar wake will accompany a local disturbance propagating with a constant velocity through the plasma. Such disturbance may be easily realized by an acoustic pulse produced in the discharge tube by an auxiliary discharge.

In this work we will report measurements of ionization waves and wakes generated in this way and give a phenomenological explanation of the observed phenomena.

2. EXPERIMENTAL RESULTS

For all of our experiments we have used a discharge tube of inner diameter 12 mm filled with neon. The experimental techniques were similar to the work of Nygaard [3]. The pulses were produced 12 times per second by discharging periodically an

*) Na Slovance 2, Praha 8, Czechoslovakia.
Ionization waves and wakes excited by an acoustic pulse

energy of about 4 joules, stored in a capacitor, into an auxiliary spark gap, situated at one end of the discharge tube (see Fig. 1a (for figures 1a–e see Appendix I, p. 922 a, b)). The resulting waves traversed first a distance of about 15 cm in neutral gas, before they reached the discharge plasma. In the respective time all of the electric processes provoked by the initial disturbance decayed, so that the pulse entering the discharge was purely acoustic. The phenomena which it provoked in the discharge were accompanied by changes of plasma luminosity, which were detected by a photomultiplier and studied by an electronic method, giving on the screen of an oscillograph similar diagrams as can be obtained by a rotating mirror display. Further details on the experimental techniques are given in [4].

In Fig. 1 there are some typical diagrams obtained by this method. Anode is always up, cathode bottom and the distance scale on the vertical axis is the same for all diagrams. Also the horizontal time scale is the same for Figs. 1b to 1e and differs for the first diagram only.

The electric spark generating the acoustic pulse induced always a pulse disturbance in the discharge circuit and, when the plasma parameters were favourable for generation of ionization waves of a certain type (p, r, or s, see [5]), it initiated the respective wave of stratification. In Fig. 1a a weak wave of the type p can be seen. The same type may be observed in Figs. 1c and 1d, while in Fig. 1e the wave of type r is best visible on the left hand side of the picture.

For our investigation are more important the phenomena, which were caused directly by the acoustic pulse. It had in all cases a velocity $c_a = \pm 450$ m/sec and it reached the discharge region about 0.4 milliseconds after its generation at the end of the tube. When propagating through the positive column, it caused some additional light emission, so that it can be seen in all diagrams as an oblique bright stripe. In the first four figures, it propagated in the direction from the anode to the cathode, while in the last diagram Fig. 1e it moved in the opposite direction.

In Fig. 1a the acoustic pulse was followed by a temporal decrease of the average plasma luminosity, which decayed with a time constant of a fraction of a millisecond. The reaction of the plasma to the acoustic pulse was hence aperiodic in this case.

Quite different is the situation in the next three diagrams, which were obtained in the same tube for slightly different discharge parameters. The acoustic pulse was here followed by a wake represented by an oscillatory process. Similar damped oscillations following an acoustic pulse were observed and described earlier by Wojaczek and in more detail by Hayess [6]. In both cases the effect under discussion was evidently essentially the same as in our case and as sketched in Fig. 2a. The authors interpreted it correctly as a process of stabilization of plasma parameters after an aperiodic disturbance, however, they did not connect its existence with ionization waves.

The oscillations detected from different places along the discharge tube are in our diagrams summarized in one picture and form a series of stripes behind the stripe representing the acoustic pulse and parallel to it. Although these stripes are very similar to the first one, they must be of other than acoustic nature, since the acoustic