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Letters to Editor

STUDY OF A HELIUM-IODINE DISCHARGE PLASMA[1]

ИЗУЧЕНИЕ ПЛАЗМЫ ГЕЛИЕВО-ЙОДНОГО РАЗРЯДА

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The present note reports on the investigation of the $He + I_2$ discharge following its characteristics in dependence upon the conditions of different values of pressure, current, mixture ratio and wall temperature.

An increasing interest in plasmas in gas mixtures containing iodine has been stimulated by the discovery of the laser lines in the middle infrared or visible regions of the spectrum [1]. A photochemical infrared laser with an oscillation at 1.315 μ, but operating in some alkyl iodides, has been developed as the pulsed high power supply for the laser fusion. The laser action on this line can be produced in an electric discharge, too. Of particular interest are the laser lines within 3 to 5 μ which seem suitable for an optical communication and atmospheric pollutant detection. In the visible range of the spectrum the $He + I^+$ laser was constructed utilizing the $He + I_2$ discharge as an active medium with electronic pumping through the reaction of He^+ with I (see [1]).

The glow discharge with iodine, either as the main gas or added to an inert gas, possesses some particular properties because of the high rate of production of negative ions, in addition of several kinds. With larger quantities of iodine, the constriction of the positive column occurs at much lower pressures than in pure inert gases and there is an enhanced tendency of the column to be unstable. The diffuse and constricted discharge forms were observed in pure iodine [2, 3] as well as in the mixture $Ar + I_2$ [4]. The particular behaviour of the negative ions or the high degree of the dissociation of I_2 together with the special boundary conditions at the walls complicate the operation of the discharge. Therefore buffer gases (He, Ar, N_2) are commonly added either to suppress instabilities or to control the electron energy distribution for the enhancement of effectiveness of the desirable processes. However, the use of the mixtures leads to appearance of new phenomena, e.g. electrophoretic effect, which change the features of the discharge.

In our experiments we used a sealed-off tube of the inner diameter 1.8 cm and the length 60 cm with a water cooled jacket and with cylindrical molybden electrodes. Two iodine reservoirs were attached to the tube near the discharge electrodes, the temperature of which was well under control. Two pairs of probes, the spacing between which was 10 cm, were placed near both the cathode and the anode ends of the discharge. The experiments were performed with stabilized current in the region $I = 1$—100 mA, at a helium pressure 670 Pa and 2000 Pa, with a partial pressure of iodine 4.2 Pa and 13.3 Pa (iodine reservoir temperature 0° and 12 °C, respectively) and the discharge tube wall temperatures 20, 30 and 50 °C. The results are summarized in Figs. 1—4. Under these experimental conditions the electric fields

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measured at the anode and cathode ends of the positive column differ most probably due to the partial electrophoretic separation of the gases and the temperature gradients. The differences were smaller at a higher partial pressure of iodine. At a smaller current and a lower content of iodine in the $He+I_2$ mixture the discharge was constricted to the axis, similarly as in the regime of higher currents (the boundaries of the constrictions K1 and K2 are marked in the Figures). At higher currents the constricted thread was moreover covered by a diffuse mantle. In the middle current range the discharge appeared to be of an ordinary diffuse type with a tendency to instability. The constricted lower current discharge stage depended on the temperature and surface quality of the walls (Fig. 1). The two sets of experimental points (open and full) of the electric field dependence vs current result from the change of the wall quality due to the deposition of iodine or its compounds on the walls during the operation of the discharge. The transition to the unconstricted form, with the current increasing, was connected with a steep change of the electric field. On the other hand, the second constricted discharge stage remained practically indifferent to changes of the boundary conditions on the tube walls. The transition to the constriction at higher currents was usually accompanied by high level fluctuations of the electric field. At greater quantities of iodine the discharge was of a diffuse type and tended to the constriction only at higher currents (Fig. 2). If the iodine reservoir was cooled to liquid nitrogen temperature, the iodine was removed from the positive column after a comparatively long time and a diffuse type of discharge was established with the electric field and colour corresponding to the discharge in pure helium (Fig. 3). This undoubtedly shows the significant role of the iodine electronegativity in the development of the constricted forms of the positive column in both current regimes. The influence of partial pressure of He

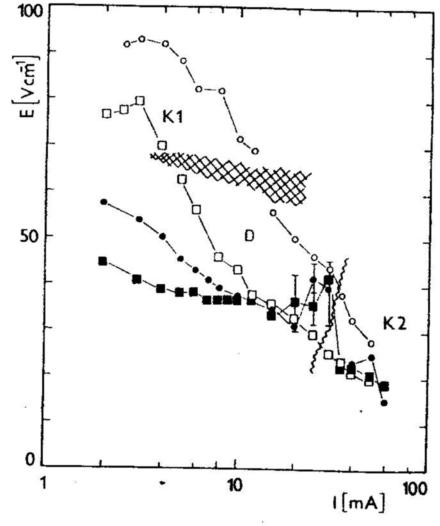


Fig. 1. Electric field versus discharge current at different wall temperatures: 20 °C — ○, ●; 50 °C — □, ■. The open points were obtained in a fresh tube and the full ones after approximately 20 hours of the discharge operation. K1 and K2 — the first and second constriction regimes, D — the diffusion region. The partial pressures of iodine were 4.2 Pa and those of helium 670 Pa.

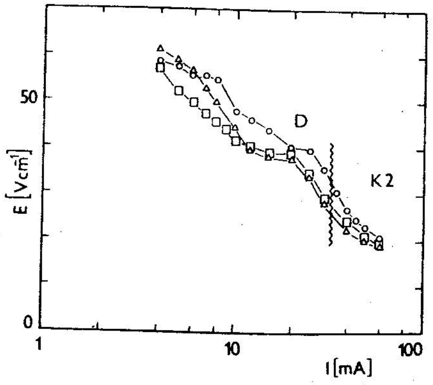
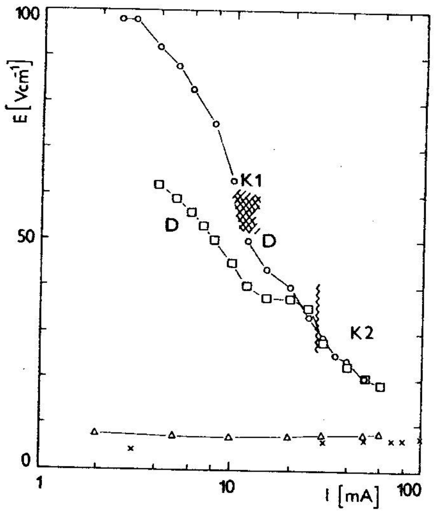


Fig. 2. Electric field versus discharge current at various wall temperatures: 20 °C — ○; 30 °C — △; 50 °C — □. $p_I = 13.3$ Pa and $p_{He} = 670$ Pa.



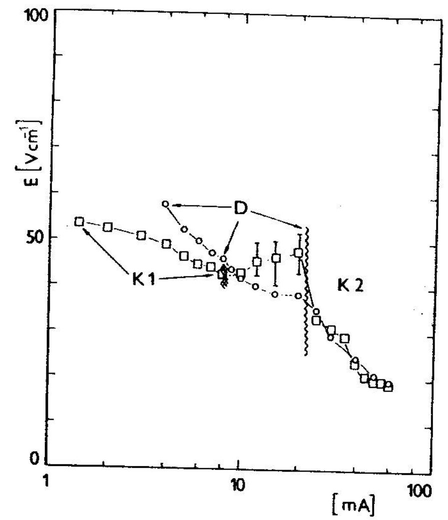


Fig. 3. Electric field versus discharge current. The partial pressure of iodine: 4.2 Pa — ○; 13.3 Pa — □; iodine reservoir cooled to the liquid nitrogen temperature — △; a special measurement in pure helium — x. Wall temperature 20 °C.

Fig. 4. Electric field versus discharge current at different partial pressures of helium: 670 Pa — ○; 2000 Pa — □. $p_I = 13.3$ Pa and wall temperature 50 °C.

as the buffer gas on the electric field gradient at constant iodine pressure is shown in Fig. 4; the influence is apparent only in the low current region.

There can be several factors which govern the column constriction in electronegative gases or in their mixtures with inert gases. According to a simple model suggested in [5] the constriction in electronegative gases results from the (radial) balance of the electrons and negative ions if the dominant loss process is the volume recombination of the negative and positive ions and the ratio of the negative ions to the electrons is sufficiently great. Under the conditions of our experiments this situation can occur in both regimes of the first and second constrictions due to the easy creation of the negative ions and also a favourable energetic distribution of electrons for the ionization of the helium atoms. The other factor influencing the constriction can be the radial electrophoretic separation of the admixture [6], which may cause radial changes in the electron energy distribution function and in such a way a strong radial dependence of the production rates of electrons and negative ions. It is obvious that the radial distribution of the admixture particles due to the electrophoresis is influenced also by the wall temperature. Conversely, detachment processes tend to broaden the radial profiles of electrons [7]. Then the closeness of the balance between detachment, recombination etc., the rates of which change with the discharge current and the electric field, may lead to the formation of either the difuse or the constricted discharge column.

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