SPECTRAL CHARACTERISTICS AND ELECTRIC PARAMETERS OF THE POSITIVE COLUMN (PC) OF THE GLOW DISCHARGE (GD) IN THE MIXTURE ($He+F_2$) AND ($Kr+F_2$)

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ABSTRACT

The present paper is devoted to the investigation of emission spectra in the visible region as well as some physical parameters (Te, n_e, E/p) of the PCGD plasma of the mixtures ($He+F_2$) and ($Kr+F_2$) on the partial composition of the fluorine. It was shown, that an abrupt change of intensity of the helium and fluorine transitions is connected with the change of physical parameters of the plasma. It is possible, that in the ($Kr+F_2$) mixture quenching processes of the type $F_2^*+Kr \rightarrow KrF^*+F$ take place.

1. INTRODUCTION

The development of high efficient lasers on eximers of the ЭT* type (Э is noble gas atom) and also the production of compounds in conditions of a strongly non-equilibrium plasma of the PCGD in the mixtures of fluorine with noble gases stimulates some interest to spectral characteristics and electric parameters of such a plasma.
In the present paper the investigations of emission spectra in the visible region have been carried out and also the physical plasma parameters (temperature of electrons, electric field strength etc.) have been measured in the ($He+F_2$) and ($Kr+F_2$) mixtures with the change of the partial composition of F_2 from 0 to 100%.

2. EXPERIMENTAL

The experimental installation, the technique of spectra measurement and the procedure of investigation of the plasma physical parameters have been described previously (1,2). In the experiments use was made of fluorine 99.5%, containing N_2, O_2 and HF as impurities, which has been produced by the low-temperature rectification. The He and Kr used were spectrally pure.

3. RESULTS

Fig.1,2 present the dependencies of relative intensities of spectral lines of He, Kr, atomic fluorine and bands of molecular fluorine on the composition of gas mixtures ($He+F_2$) and ($Kr+F_2$). In the case of the fluorine with krypton mixture the dosage of the composition began from traces of Kr or F_2 to determine their minimum concentrations in the mixture, recorded by the spectrometer scheme. From Fig.2 it follows that in the mixture ($Kr+F_2$) the excitation states of Kr and F_2 are registered in the overall investigated interval of the % composition of mixtures. In that case the intensity of Kr

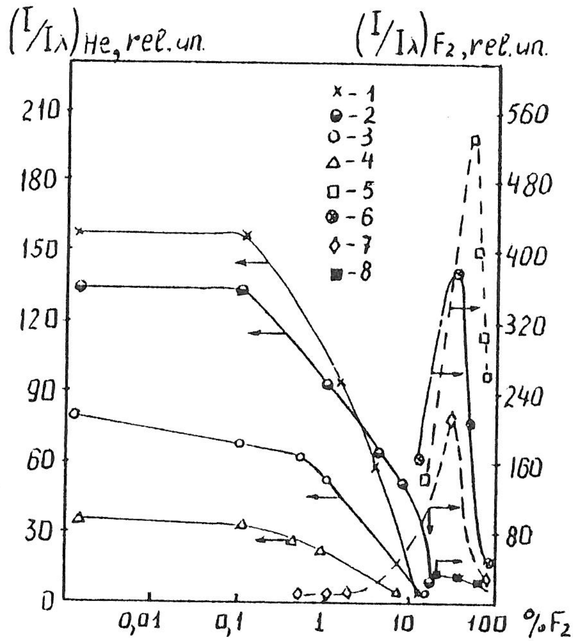
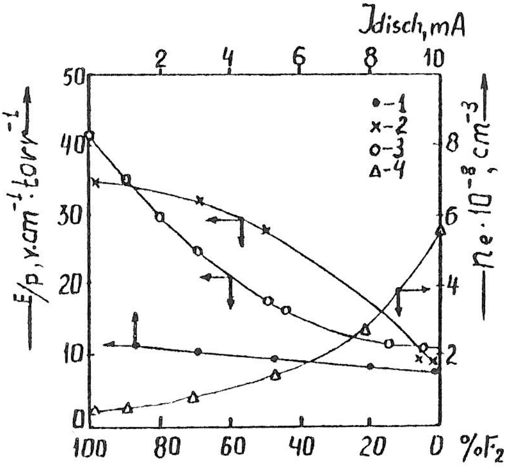


Fig.1. The dependence of the intensity of the emission spectrum in the ($He+F_2$) mixture on the composition. (P=3 torr, I_{disch}=3mA).
1. He-4471,48Å 2. He-7065,19Å
3. He-6560,4Å 4. He-5875,62Å
5. F_2^*-4225,0Å 6. F_2^{+*}-4539,2Å and 4513,2Å 7. F_2-6517,2Å
8. F^*-7800,212 and 7754,696Å

line radiations exceeds by more than two orders the intensity of fluorine lines and bands. In the ($He+F_2$) mixture the situation is completely different. In the presence of ~ 10% F_2 the lines of excited He are practically absent in the radiation. If in the case of the ($He+F_2$) mixture the difference in intensities of emission spectra can be related to the significant difference of the excitation thresholds (22-23 eV - He (3)) and ~ 12 eV for excitation of $C^1\Sigma^+$ electron livels mixtures (Fig.3.2) results in the change in E/P from the values in the pure F_2 to the values in the pure He. The change of electron temperature in the plasma is in agreement with the change of the electric field strength (Fig.4.1;4.2). The increase in the rate of diffusion destruction with the decrease of F_2 portion in mixtures (Fig.4.3;4.4) agrees with the increase of electron concentration (Fig.3.4). At the same time, the estimations of ionization rates 1. $F_2+e \rightarrow F_2^+ + 2e$ (1.1) 2. $F_2+e \rightarrow F^- + F^+ + e$ (1.2) taking into account only direct processes from expressions:



1. $\Gamma_+ = K n_e N_{F_2}$ (2.1)

2. $K = \eta \sigma_{thr} T_e^{1/2} \frac{b-1}{b^3} \times$

$\times (2 + b\frac{U_i}{T_e}) \exp\left[-\frac{U_i}{T_e}\right]$ (2.2)

Fig.3. The dependence of the reduced electric field strength (1-3) and the electron concentration (4) on the current of discharge and the plasma composition. I_{disch}=3mA, P=3 torr. 1. He 2.(He+F_2) 3.(Kr+F_2) 4. e,(Kr+F_2)

show that they are equal to $2.6\cdot10^{16}$ and $1.5\cdot10^{+15}$ $cm^{-3}.sec^{-1}$, respectively. In estimating it was assumed that the electron energy distribution function is Maxwell and the total ionization cross-section was approximated by Fabricant function (7) . The data from Fig.3 and 4 and the value of estimations show that in the pure fluorine the charges are destroyed mostly in the volume recombination processes. The calculations carried out for noble gases (Kr, Ar, Ne) with allowance for experimental investigations of distribution functions by the second harmonic method and the comparison of calculation data with the experiment of diffusion destruction of the charges are indicative of the diffusion mechanism. Thus, as the partial composition gas charges, the character of charge destruction and the mechanism of discharge burning change, which causes the change of the plasma physical parameters.
The analysis of data from Fig.1,3,4 anables one to suggest that in the (He+F_2) mixture the change in intensities of He

of the fluorine molecule (4) , for the ($Kr+F_2$) mixture, taking into account that excitation potentials for Kr and F_2 are approximately similar (Kr-8112 9Å - 11.45 eV; 8059,5Å - 12,1 eV - 7601 54Å - 11,55eV (5)), the explanation from the energy point of view is difficult. In the general case the intensity

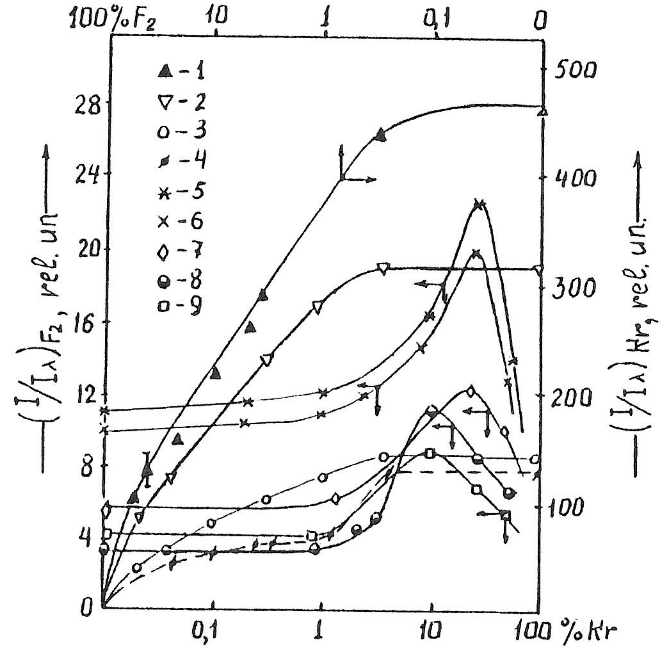


Fig.2.The dependence of the intensity of the emission spectrum in the ($Kr+F_2$) mixture on the composition P=3 torr, I_{disch}=3 mA
1.He-8112Å 2.Kr-8059Å 3.Kr-7601Å
4.Kr-7685Å 5.F_2^{+*}-4513,2 and 4539,2Å 6.F_2^*-4823Å 7.F_2^*-5423Å
8.F_2^*-5092Å 9.F^*-7754,7 and 7800,2Å

of ($4^3D-2^3P^0$),($3^3S-2^3P^0$) and ($3^3D-2^3P^0$) helium transitions decreases sharply in the presence of ~ 1%F_2. The presence of maximum intensities of the molecular fluorine ($C'\Sigma - B'\Pi$),the molecular ion F_2($A'\Pi - X^2\Pi$) (6) and the atomic fluorine ($nP^2D^0 - nP^2P^0$) transitions (the excitation threshold 14.6eV (3) in both mixtures is connected with the positive column contraction phenomenon (2) .
Additional information on spectral characteristics of the positive column in the ($He+F_2$),($Kr+F_2$) mixtures can be obtained analyzing physical parameters of mixtures of a molecular fluorine with noble gases depending on the composition (see Fig.3,4).The decrease in fluorine partial pressure in

radiative transitions ($4^3D-2^3P^o$), ($3^3S-2^3P^o$), ($3^3D-2^3P^o$) having practically the same transition cross-sections as well as bands and lines of fluorine, is due mainly to the change in physical parameters of the plasma ($\mathcal{E}$, E/P, n_e etc.). In the ($Kr+F_2$) plasma the intensity of emission bands of F_2 and of the atomic fluorine is two orders of magnitude less that those of krypton in this mixture and fluorine in the ($He+F_2$) mixture in conditions of almost unchangeable physical parameters of plasma (Fig.3.4).Taking into consideration the close values of threshold excitation energies of transitions in krypton and fluorine this fact can be explained by the quenching processes:

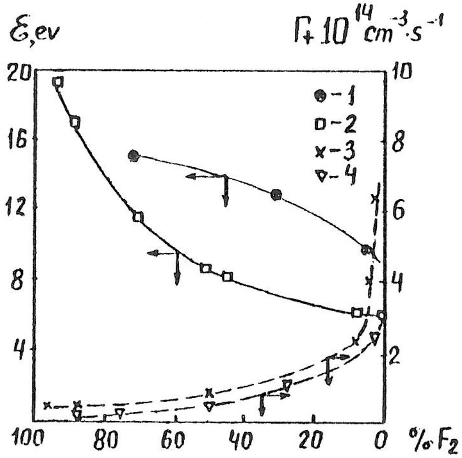


Fig.4. The dependence of the mean energy of electrons (1,2) and the rate of diffusion destruction of charges $\Gamma_{+diff.}$ (3,4) on the composition (P=3 torr, I_{disch}=3mA). 1.($He+F_2$) 2.($Kr+F_2$) 3.($He+F_2$) 4.($Kr+F_2$)

$$F_2^* + Kr \rightarrow F_2 + Kr^*$$

$$F_2^* + Kr \rightarrow KrF^* + F$$

which, probably, are of a resonance character.
It is known that the processes of the type:

$$Э^* + F_2 \rightarrow ЭF^* + F$$

where - Ar, Kr, Xe play an important role in eximer lasers.

The rate constant of such processes has the value $10^{-10} cm^3 sec^{-1}$ (8).

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