INVESTIGATION OF FLUORINE DISSOCIATION IN THE POSITIVE COLUMN (PC) OF THE GLOW DISCHARGE (GD) IN THE PRESENCE OF NOBLE GASES. SPECTRAL CHARACTERISTICS AND PHYSICAL PARAMETERS OF PCGD PLASMA IN FLUORINE, NEON AND ($Ne+F_2$) MIXTURE.

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ABSTRACT

The fluorine dissociation rate, physical parameters and emission spectra in the mixture ($Ne+F_2$) on the discharge current (1-40mA), gas pressure (0,25-3,0torr) and partial composition of mixture (0-100% F_2) have been investigated. Efficiency of fluorine atoms generation rises with increasing portion of neon in the gas mixture. Main dissociation mechanism is dissociation attachment of electrons.

I. INTRODUCTION

The PCGD plasma in fluorine and fluorine mixtures with noble gases is used for the synthesis of binary Kr and Xe fluorides (1). Besides, the plasma generated in the noble gas-halogenide medium is used to obtain inverse population of the levels of eximer monohalide molecules of the BG^* type where B is Ne,Ar,Kr,Xe, G is F,Cl,Br (2). The dissociation of fluorine molecules takes place in the plasma, as well as the formation of excited atoms and radicals participating in syntheses of stable and unstable molecules (3,4). Therefore investigations of spectral characteristics, physical parameters and fluorine dissociation rate are of interest.

2. EXPERIMENTAL

A spectrally pure Ne and fluorine mixed with O_2,N_2,HF(0,5%) were used in experiments. Methods of measuring dissociation rate and physical parameters are described in (5,6). The spectral investigations were performed in the 14mm diameter gas-filled gap quartz windows on the end face planes. The discharge emission spectrum was recorded by means UM-2 monochromator with the ФЭУ-79 photomultiplier. On being amplified in the Ф-359 direct-current amplifier the signal was recorded on the 10mV КСП-4.

3. RESULTS AND DISCUSSION

Dependences of the fluorine dissociation rate in the ($Ne+F_2$) system on the Ne percentage (Fig.1), gas pressure and discharge current (Fig.2) have been investigated.

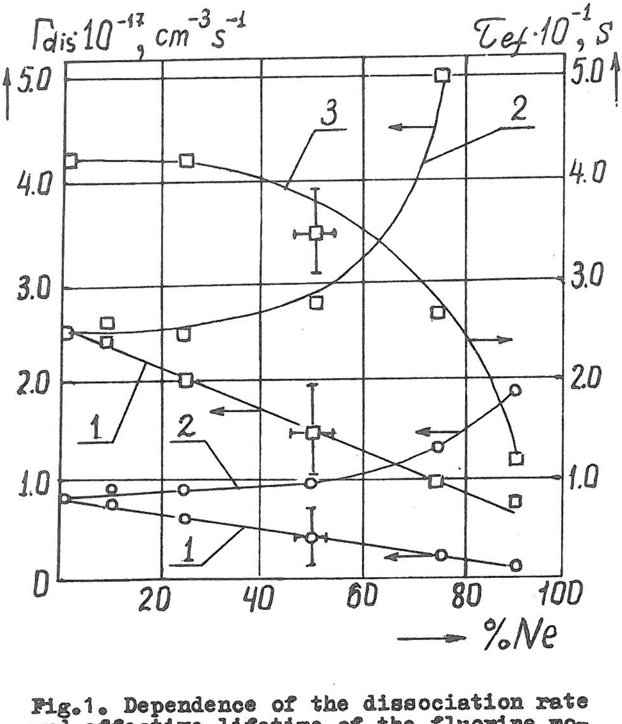

Fig.1. Dependence of the dissociation rate and effective lifetime of the fluorine molecules on the mixture composition. P = 3 torr; 1 - dissociation rate; 2 - reduced value of the dissociation rate; 3 - effective lifetime. o-I disch.=2 mA; □-I disch.= 30 mA.

A decrease in the F_2 dissociation rate with decreasing its partial pressure in the mixture as well as the linear dependence of the dissociation rate on the discharge current are indicative of the mechanism of dissociation initiated by the electron impacts $F_2 + e \xrightarrow{K} F^- + F + 2.1$ eV.

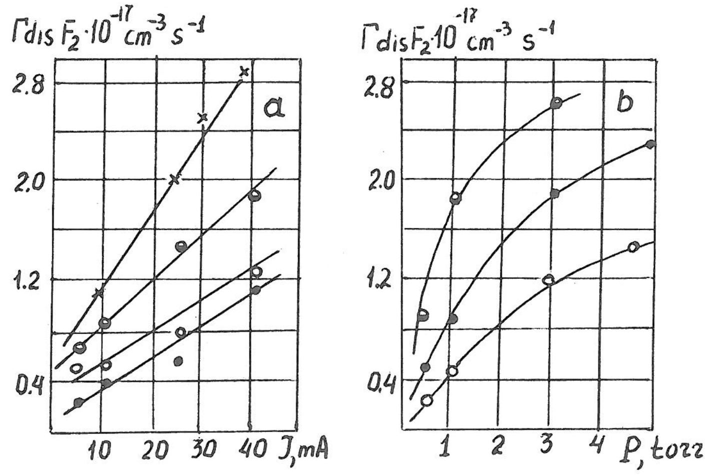

Fig.2. Dependence of the dissociation rate of F_2 on current (a) and discharge pressure (b) in various compositions of the mixture. a) P=3 torr, • –25%F_2; o –50%F_2; ⊖ –75%F_2; x–100%F_2; b) $I_{disch.}$= 30 mA; o–25%F_2; • –75%F_2; ⊖ –100%F_2.

The fluorine dissociation rate is described by equation $\Gamma_{dis} = KN_{F_2}n_e$, where $K = \int_{u_{thr}}^{\infty} \sigma(u)\sqrt{u}\, f(u)\, du$ is the reaction rate coefficient, N_{F_2} and n_e are the fluorine and electron concentrations in the discharge, respectively, $\sigma(u)$ is the process cross section, u is the energy of electrons in eV and u_{thr} is the energy threshold. With the decrease in N_{F_2} by an order of magnitude Γ_{dis} reduces by a factor of 2 to 3 only, which results in the increase of a reduced value of the dissociation rate $\Gamma_{red} = \frac{\Gamma_{dis} \sum P_i}{P_{F_2}}$ (Fig.1, curve2) and indicates the decrease in the effective lifetime of the fluorine molecules $\tau_{ef} = \frac{N_{F_2}}{\Gamma_{dis}}$ (Fig.1, curve 3). This is caused by changes in K and n_e. Increase of the electrically negative F_2 in the $(Ne+F_2)$ mixture changes n_e only by 20–30%, therefore change in K is determinative. The measurements showed that the reduced value of the electric field strength E/P decreases by a factor of 2 to 3 with an increase of neon percentage from 10% to 80%, which is indicative of the increase of Towndsend coefficient of the dissociation attachment, that is, results in the increase of K. An electron temperature T_e decreases at the same time, which, with the Maxwellian character of the distribution kept, also favours arise of K because of increasing the portion of electrons having energies in the range of 0 to 3eV where $\sigma(u)$ has maximum value (7). The calculations showed that in the presence of Ne the energy output of the fluorine atoms $W = \frac{\Gamma_{dis}}{W_{spec}}$ (Wspec is the energy introduced to the discharge) falls from $0.18\frac{at}{eV}$ (100% F_2) to $0,07\frac{at}{eV}$ (90% Ne) and the reduced value $W_{red} = \frac{W \Sigma P_i}{P_{F_2}}$ increases simultaneously from $0,18\frac{at}{eV}$ to 0,7 at/eV, respectively, which indicates an efficiency increase of fluorine atom generation. It was shown in (6) that in the discharge of pure fluorine the destruction of the charges occurs mainly in the volume processes. The addition of Ne having a higher ionization potential ($U_i^{F_2}$ =16,6eV, U_i^{Ne} =21,3eV) to the plasma results in a decrease of E/P, Te and simultaneously the rate of the diffusion destruction of the charges rises by an order of magnitude, this rate being calculated on the basis of the values of saturation ion current on the probe. That shows the increasing role of ambipolar mechanism.

Neon and fluorine line intensities under PCGD conditions in pure Ne, fluorine and (Ne+F_2) mixture versus the current (1-15 mA), gas pressure (0,25-3,0 torr) and partial mixture composition (from 0.5 to 100% F_2 (Fig.3) also investigated. It has been shown that the radiation intensity rises with increasing discharge current. The linear dependence of the A^2P-X^2P transitions of the molecular ion, $C^1\Sigma^+-B^1P$ molecular fluorine and $3s^2P-2p^2D^o$ atomic fluorine on the discharge current indicates that population of the excited levels is accomplished mainly due to the electron impact: $F_2+e \rightarrow F_2^{+*} + 2e$; $F_2+e \rightarrow F_2^* + e$; $F+e \rightarrow F^*+e$.

A more complicated character of emission intensity variations caused by gas pressure is due to change in the plasma physical parameters (deviation of the electron distribution function from the Maxwellian one, n_e electron concentration variations, etc.) resulting in changing the conditions of discharge burning. Almost complete vanishing of the Ne lines in the mixture with fluorine at fluorine concentration of 5% is due to a higher excitation threshold of transitions in Ne compared to that of the F_2 lines and atomic fluorine transition lines. Invariability of line intensities of the $3s^2P-3p^2D^o$ atomic fluorine transition within the F_2 concentration range from 20 to 100% is indicative of hindering the dissociation process $F_2+e \rightarrow F+F+e$ both due to decreasing n_e with an increase in the concentration of the electron-capturing component and due to a change in the reaction rate coefficient resulting from a change in other plasma parameters (reduced strength of the electric field, temperature of electrons and heavy particles *Th.p.* etc.).

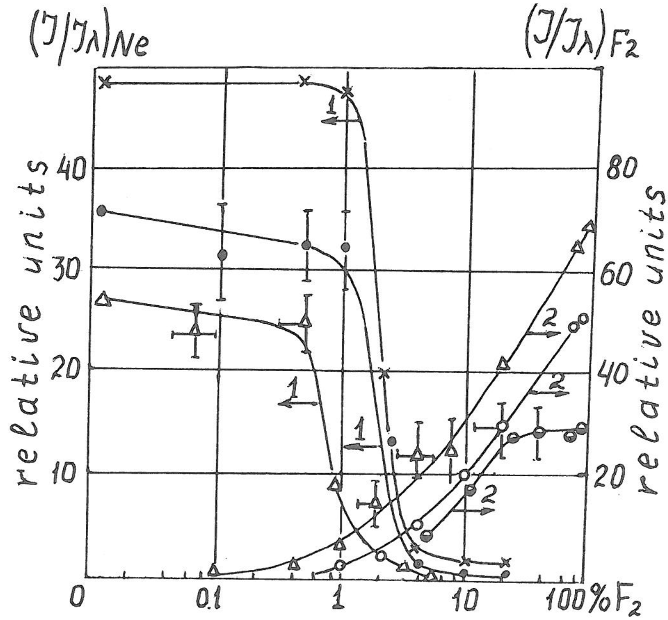

Fig.3. Dependence of the intensity of the Ne and F_2 discharge emission spectrum on the partial composition of the mixture, 1 - neon, 2 - fluorine. x-6402,25Å; ● -5852,49Å; Δ -7032,41Å; Δ- F_2^*- 4823,0Å; ○ - F_2^*-5495,7Å; ⊖ - F^*-7800,21Å; 7754,496Å

Thus change in the plasma physical parameters (E/P, Te, Th.p. etc) in the presence of Ne facilitates the fluorine atoms generation, increases the dissociation rate coefficient K and improves an important energy parameter, the fluorine atom output, by one eV of the energy introduced to the plasma. The main mechanism causing the change in the F_2 dissociation rate is the dissociation attachment of the electrons.

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