Obtaining of ArF^+ Ions in Non-Equilibrium Ion-Molecular Energy-tense Systems

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Abstract

Active particle and ion composition are considered, including ArF^+ ions, taking part in cryogen experiment in the synthesis of molecules $SbF^-_6\ ArF^+$, in non-equilibrium energy-tense systems of mixtures $Ar + F_2$. The injected energy value up to $1O^6$ ($J/m^3\ s^2$), the length of impulse being $1O^{-5}$s and the period $1O^{-3}$s. Kinetic analysis showed non-maxwellian character of the function of electron distribution in energy and the impact of considerable amounts of negative ions ($n\_/n_e=1O^2$, $n\_$ is F^- ions concentration) upon physical parameters of processes. Ion recharging $Ar^+ + 2Ar \rightarrow Ar_2 + Ar$ and dissociative recombination $Ar^+_2 + e \rightarrow Ar(^3P_2) + Ar$ processes play an important role in decomposing plasma. Mass-spectrum analysis of ion composition on QMGS 11 and registration scheme Polarity Control of Balsers was compared to solving basic kinetic problem in self corridinated form. Concentrations of ArF^+ up to $1O^{17}$ m^{-3} were obtained with ionisation level in mixture reaching $1O^{-5}$.

1. INTRODUCTION.

The development of the physics and engineering of pulsed excimer lasers as well as the successful preparative synthesis of inert-gas fluorides in a low-temperature plasma have stimulated studies of the radiation spectra and kinetic parameters of plasmas of mixtures of molecular fluorine with inert gases. References 1 and 2 discussed the influence of the partial composition of plasmas of mixtures of molecular fluorine with inert gases on the physical parameters and spectral composition of a steady-state discharge. The pulsed nature of the introduction of energy for the purpose of obtaining significant concentrations of active particles [Ar ($^3P_2$)] and [F] that participate in the heterogeneous synthesis of molecules of the type $\{SbF^-_6ArF^+\}$ and the population of the upper working levels of excimer and excimplex molecules with the participation of ions and excited atoms complicate the kinetics of ordinary collisions and chemical reactions in the volume. The purpose of this paper is to propose a methodology for the diagnostics of active particles, to study the relationship of the characteristic times of the physical and chemical processes, the heating of the electrons, and the temperature dependencies of the dissociative-recombination constants of $A^+_2(X^2\ \Sigma_u)$ ions with electrons and the reaction and conversion and of electronic non adiabatic processes with the participation of metastable particles in different regions of pulse shaping. Molecular ions ArF^+ may play of important part in the analysis. To register the presence of above-mentioned ions is the aim of the present paper.

2. EXPERIMENTAL AND CALCULATIONAL METHOD.

We studied pulsed - discharge plasmas in $Ar + F_2$ mixtures under conditions of direct synthesis of fluorine compounds with inert gases $N = 7.2x1O^{16} - 9x1O^{17}cm^{-3}$. The magnitude of current pulse was about O.1 A. The pulse width, repetition period, and radius of the discharge device were $1O^{-5}$sec, $1O^{-3}$sec and O.7 cm. The energy distribution function of the electrons (EDFE) was found by numerically solving the kinetic Boltzmann equation by the iteration method. The particle concentrations were determined by solving a system of ordinary differential equations (ODEs).

The block-diagram of the solution can be written as follows:

(a) The calculation of the particles concentrations according to the given coefficients and the equation system

$$n' = f(n, n, ..., n, t);\ n = ...$$

is carried out by the subprogram S2STIF.

(b) Assignment AM-7 = J/W * e. The calculation of the field intensity referenced to the concentration of neutral particles E/N by using the equation of current and the functions W (E/N); $I(W_d)$; $W_d=W\ (E/E_0)^\alpha$ from (a) we have

$$E/N = (E/N)_0 \cdot \left(\frac{I(W)}{eS\left(W_d n_e + \sum W_{di} n_i\right)} \right)^{1/\alpha}$$

which is carried out by the subprogram DIFFUN.

(c) The calculations of the coefficients depending on the E/N field through FREE

$$K = K\ (E/N);\ D = D\ (E/N)$$

is carried out by the subprogram COEF. Mass-spectrum investigation were carried out on Ion Polarity Control QPS 1O1 of Balzers.

3. RESULTS AND DISCUSSION.

Examples of experimental data and model calculations are shown in Fig. 1. The reliability of these results is indicated by the fact that, for plasma development times $\tau_p \sim 10^{-5} - 10^{-4}$ sec, the calculated E/N values agree with the experimental data in a steady - state plasma (Fig.1, curves 1, 1', 7 and 10'). Quasi neutrality of the plasma (Fig. 1, curves 2, 4, 6, 2', 4', 6' and 7') is achieved only for times $\tau_p > 10^{-5}$ sec. The time of establishment of the concentration $[Ar(^3P_2)]$, $\tau_p < (2\text{-}6)\times10^{-5}$ sec (Fig. 1, curve 8) corresponds to the completion of steady-state plasma formation N = const, E/N = const (Fig. 1, curves 1 and 1'). Exceptions are [F] (Fig. 1, curves 3 and 3') and the establishment of a degree of dissociation of fluorine in the molecular plasma $[F] / [F_2] < 2.1\times10^{15} / 9\times10^{16} = 2.3\times10^{-2}$ and $[F] / [F_2] = 1.3\times10^{15}/3.5\times10^{16} < 3.6\times10^{-2}$ in an Ar + F_2 mixture when $\tau_p < 2\times10^{-3}$sec, which indicates a multichannel character of the process of forming the fluorine atoms; this multichannel character causes high atomic concentrations in the afterglow as well.

The conformity of Raman spectrum SbF^-_6 analysis, mass - spectrum analysis (Ar from the solid phase, Table 1.), and the kinetics of active particles absorbtion $Ar(^3P_2)$, ArF^+... are obtained for the stabilisation of Ar in the solid phase in form $\{SbF^-_6ArF^+\}$.

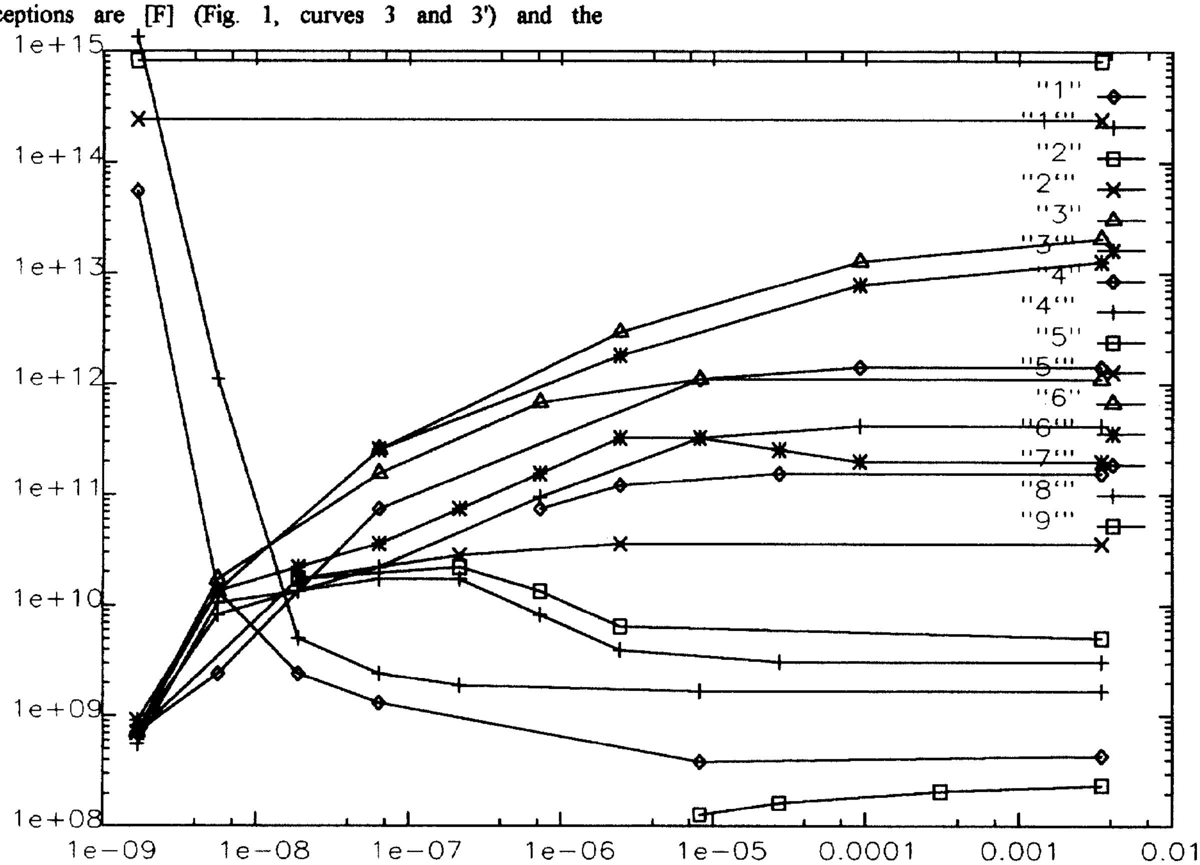

FIG.1. Development of a pulse in a plasma of molecular fluorine and Ar + F_2 mixtures. 1- 7 - F_2; 1' - 10' - Ar + F_2, $N_{F_2}=9\times10^{17}$sm^{-3}, $I_p=10^2$mA. 1 - E/N, 2 - n_e, 3 - [F], 4 - [F^-], 5 - [F_2], 6- [F^+_2], [ArF^+], 7- E/N - experimental points. F_2:Ar=1:1; $\Sigma N_j=7.2\times10^{16}$sm^{-3}, $I_p=10^2$mA. 1 - (E/N)x2; $\tau_p = 10^{-2}$sec, E/N=33Td; $\tau_p = 10^{-4}$sec, E/N=33,6Td. 2' - n_e, 3' - [F], 4' - [F^-], 5' - [F_2]=[Ar], 6' - [Ar^+], 7 - [F^+], [F^+_2], [F^+]/[F^+_2]=3; [ArF^+], 8' - $Ar(^3P_2)$, 9' - $F(3^4P)$; 10' - E/N - experimental points - = 1'. 3, 3', 5, 5' x 10^2.

Table 1.

P, torr	F^+	F^+_2	Ar^+	ArF^+	Ar^+_2	Ar_2F^+	F^-	F^-_2	Ar^-
0.12	450	2	32	1.3	0.8	0.6	15	1	7.6
0.50	230	0.4	15	0.4	-	0.4	7	0.5	3.8

4. References.

1. V.V. Zaitsev, E.Yu. Zverevskaya, V.D.Klimov et al. Zh. Prikl. Spectrosk. 35, 765 (1981); Opt. Spectrosk. 51, 448, (1981) [Opt. Spectrosk. (USSR), 51 (1981)].
2. V.D. Klimov, V.A. Legasov and V.V. Zaitsev, in Int. Symp. Plas. Chem. (10 - 14 Aug. 1981). Edinburgh, Scotland, 1981, p.58.