INVESTIGATION OF THE WORK CONDITIONS AND CHARACTERISTICS OF MULTIWAVE EMITTERS ON CHLORIDES AND FLUORIDES OF RARE GASES

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We present the results of a design and systematic investigation of spectral, temporary and resource characteristics of an electrodischarge excimer emitter with radiation on 175 nm ArCl (B-X) / 222 nm KrCl (B-X) / 236 nm XeCl (D-X) / 258 nm Cl_2 (D'-A') / 308 nm XeCl (B-X); 175 nm ArCl (B-X) / 193 nm ArF (B-X); 222 nm KrCl / 249 nm KrF / 258 nm Cl_2^* / 308 nm XeCl / 353 nm XeF. Active media of lamps were formed by gas-mixtures: Ar/Kr/Xe/Cl_2 , Ar/CF_2Cl_2 , He/Kr/Xe/CF_2Cl_2 , with the help of a powerful transverse discharge with a spark preionization. The optimum pressure of the Ar/Kr/Xe/Cl_2 mixture is 15-20 kPa, whereas the partial pressure of chlorine is 0.2–0.4 kPa. In order to obtain bands of comparable brightness, the partial pressure of Kr and Xe atoms should be in the range 0.2–0.5 kPa.
Using the CF_2Cl_2 molecules as unique carriers of Cl and F atoms, the multiwave operation mode of excimer emitters with brightness ration Kr and Xe chlorides to fluorides as 9/1 is also realized. The optimal content of CF_2Cl_2 molecules was 0.008–0.01 kPa (Ar/CF_2Cl_2 mixtures). Correlation of B-X-bands brightness of ArCl and ArF was 10. The radiation expectacy in the multiwave mode reached 5×10^3–1×10^5 pulses. Such emitters can be used in pulse photometry, high energy chemistry, biology and medicine.

1. Introduction

Excimer emitters (Eem) with transverse discharge (TVD) pumping [1, 2] are most powerful of the wide class of such electric-discharge radiators. Such radiators radiate as a rule, on a single wavelength. The investigation of a multiwave mode of operation of such excimer emitters is of interest for a number of applications in pulsed photometry, for acting simultaneously and selectively on individual high-energy bands of chemically or biologically active compounds.

This communication describes a study of the conditions for simultaneous formation of ArCl(B), KrCl(B), KrF(B), Cl_2(D'), XeCl(B) and XeF(B) molecules in a TVD-plasma based on Ar/Kr/Xe/Cl_2, Ar/CF_2Cl_2, He/Kr/Xe/CF_2Cl_2 and He/Kr/Xe/SF_6/HCl mixtures.

2. Experimental

TVD-pumped emitters had 18×2,2×(0.5–1.0) cm^3 active media with an interelectrode distance of 2.2 cm. A schematic diagram of the radiation source is presented in [3, 4]. Preionization of the interelectrode space is performed with the help of two rays of spark gaps with parallel triggering. A thyratron TGI 1000/25 is used as a switch for the pulsed power supply of the TVD. The discharge was struck by means of a double-loop LC-circuit in which the capacitance of the main storage capacitor was 30 nF and total capacitance of the peaking capacitors was 9,4 nF.

The radiation from the TVD plasma was recorded using a half-meter Seya-Namioka vacuum monochromator. The TVD chamber is tightly connected to the input slit of the vacuum monochromator through a CaF_2 window. A FEU-142 photomultiplier with a LiF window served as the photodetector. The working wavelength range of the vacuum spectrometer was 130-350 nm. The relative calibration of the vacuum monochromator+FEU-142 system was carried out in the range Δλ=165–350 nm on the basis of the continuous radiation of hydrogen molecules. The emission in range Δλ=200–600 nm was studied by using an MDR-2 monochromator and photomultiplier "FOTON". The power and temporal characteristics of emission in the UV spectrum range were controlled with the help of an IMO-2H device, a 14-FC elecronic linear amplifier and 6LOR-04 high-speed oscilloscope.

3. TVD in Ar/Cl_2, $Ar/Kr(Xe)/Cl_2$ and $Ar/Kr/Xe/Cl_2$ Mixtures

The main bands in TVD plasma on Ar/Cl_2 mixtures are 258 nm Cl_2 (D'-A')/ 175 nm ArCl (B-X). Figure 1 shows the dependences of the emission intensities of the Cl_2^* and $ArCl^*$ bands on the content of Cl_2 molecules and argon atoms in a discharge in the Ar/Cl_2 mixture. At U_{ch} ≤12,5 kV, the optimal content of Cl_2 is 0,2-0,4 kPa.

For the Cl_2^* band, a broad maximum of emission intensity is seen in the range of argon pressure in the TVD of 8-15 kPa, whereas for the B-X band of ArCl it is shifted to the region of 15-25 kPa. For TVD on the Ar/HCl and He/Ar/HCl mixtures, the optimal content of HCl molecules is 80 Pa and the maximal intensity of ArCl(B-X) emission decreases by 2–3 times. Such a behavior of the intensity of the ArCl(B-X) band can be due either to lower efficiency of ArCl(B) molecules generation as a result of the "harpoon" reaction Ar^*+HCl(v)→ArCl(B)+H as compared to the corresponding reaction wich Cl_2 or to a considerable absorption of VUV radiation by hydrogen chloride. In the TVD based on $Ar/Kr/Cl_2$, $Ar/Xe/Cl_2$ and $Ar/Kr/Xe/Cl_2$ mixtures, the main radiation was concentrated at 175, 222, 258 nm; 175, 236, 258, 300 nm and 175 nm ArCl (B-X) / 222 nm KrCl (B-X) / 236 nm XeCl (D-X) / 258 nm Cl_2 (D'-A') / 308 nm XeCl (B-X) (Fig.2). A stable ignition of the TVD was achieved for the charging voltage U_{ch}≥4.0 kV. An increase in the charging voltage from 4 to 12 kV led to the increase in the brightness of all of the observed bands by a factor of 2–5.

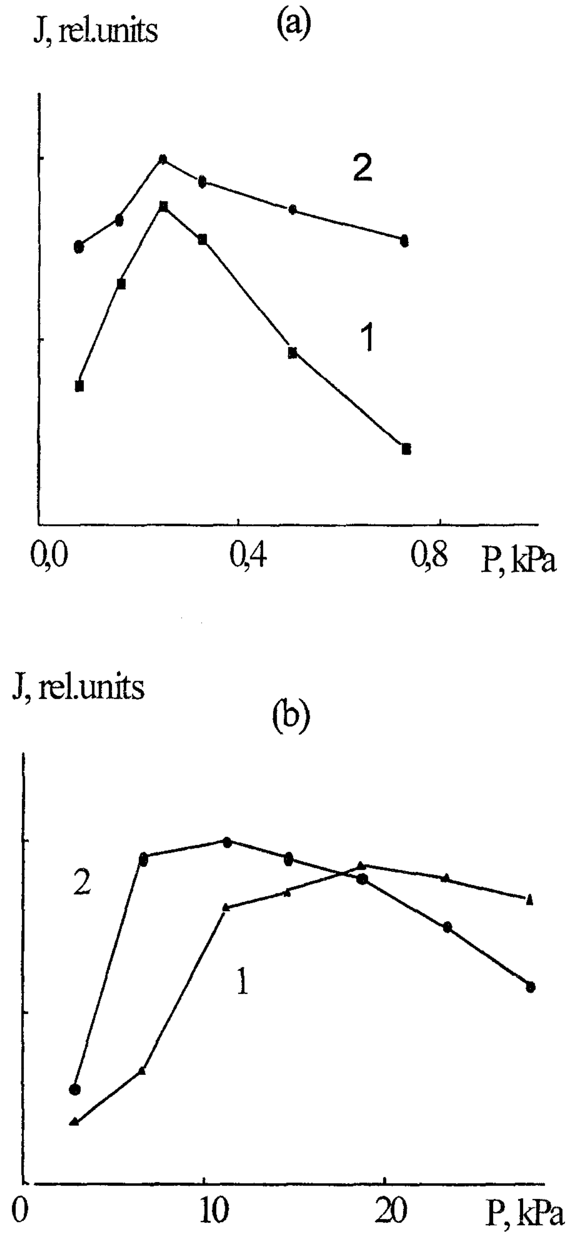

Fig. 1. Dependences of emission intensity of the bands λ=175 nm ArCl (1) and 258 nm Cl_2^* (2) on the content of chlorine molecules (P_{Ar} =13,3 kPa, U_{ch}=10 kV) (a) and argon atoms (P_{Cl2}=0,24kPa, U_{ch}=10 kV) (b) in the discharge when operating on the Ar/Cl_2 mixture.

The optimum argon pressure is in the range 15–20 kPa. The greatest brightness of the XeCl (D-X) radiation was observed at reduced pressures of the mixture (P≤3 kPa). At moderate charging voltage (U_{ch} ≤ 12 kV) and $P \geq 30$ kPa, contraction of the TVD was observed. XeCl(D,B-X), KrCl(B-X), ArCl(B-X) and Cl_2(D′-A′) radiation bands of comparable brighness could be obtained in the regions of low (P=5–10 kPa) and high (P=20–30 kPa) pressures of the Ar/Kr/Xe/Cl_2 mixture.

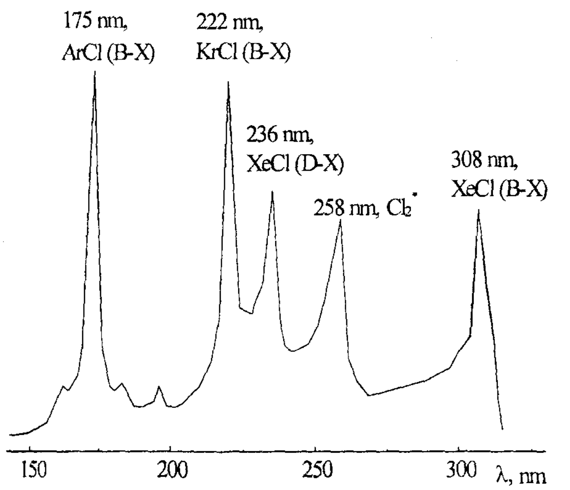

Fig. 2. Emission spectrum of an electric-discharge plasma formed from Ar/Kr/Xe/Cl_2 mixture (P=15 kPa, U_{ch}=12 kV).

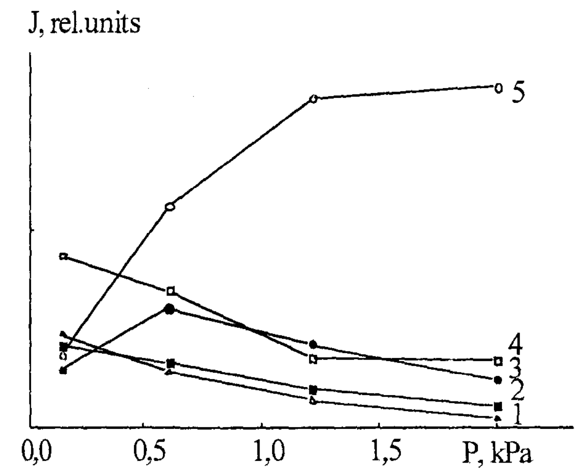

Fig. 3. Dependences of the brightness J of bands with λ=175 nm (1), 222 nm (2), 236 nm (3), 258 nm (4) and 308 nm (5) in a TVD formed the Ar/Kr/Xe/Cl_2=13.3/0.4/P_{Xe}/0.24 kPa mixture on the xenon pressure (U_{ch}=12 kV).

An increase in Xe pressure (in Ar/Xe/Cl_2 and Ar/Kr/Xe/Cl_2 mixtures) leads to the decrease in the brightness of bands at λ=236, 222 and 175 nm and to the increase in the brightness of the band at λ=308 nm. When the Xe pressure was increased above 0.1 kPa, the saturation of the growth (decrease) of the brightness of all the bands is observed at Xe pressure of 0.5 kPa (Fig. 3). The bands of comparable brightness can be obtained in the investigated mixture at the xenon pressure of 0.2-0.5 kPa.

For the TVD plasma with p<10-20 kPa the role of the ion-ion recombination ($Ar^+ + Cl^-$ +[Ar]→ArCl (B,C,D)+ [Ar]) diminishes, as the pressure decreases from 100 to 10 kPa, since the rate constant for the given reaction decreases by an order of magnitude [5]. In the initial stage of the discharge, the harpoon reactions: Ar ($^3P_2$)+Cl_2→$ArCl^*$+Cl (k= 7×10^{-10} $cm^3\,s^{-1}$ [6] predominates. The excitation of the rare-gas atoms in the TVD plasma is important for this reaction.

The radiation-intensity distribution in the TVD plasma is therefore determined to a large extent by the transfer of energy via the Ar^*-Kr, Xe channel [6, 7], which can also be interpreted as the formation of excimer molecules in a multicomponent active medium.

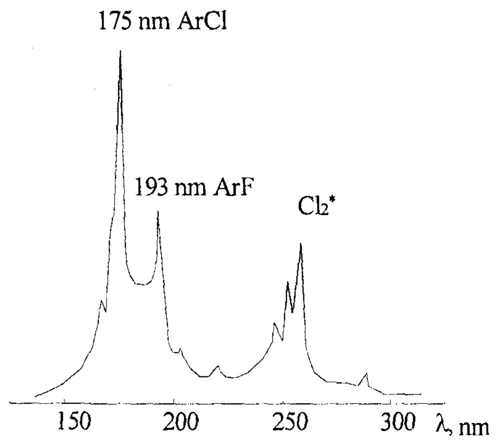

Fig. 4. Spectra emission of plasma TVD in mixtures Ar/CF_2Cl_2=12/0.04 kPa.

4. TVD in Ar/CF_2Cl_2 and He/Kr/Xe/CF_2Cl_2 Mixtures

Plasma radiation spectra in the range 130–150 nm and brightness of the 175-nm

ArCl, 193-nm ArF and 258-nm Cl_2^* bands, obtained in the discharge in the mixture of Ar/CF_2Cl_2 = (1-15)/0,008-0,15) kPa were investigated. It was shown that the given TVD was a multiwave source on the ArCl, ArF and Cl_2 (D'-A') molecular transitions (Fig. 4). The optimal content of CF_2Cl_2 molecules was 0.008-0.01 kPa, Ar atoms – 10–15 kPa (Fig. 5). The ratio of the B-X band brightnesses in ArCl and ArF was 10 [8]. This value is approximately equal to the ratio of [Cl^-] and [F^-] ion densities, generated in the reaction of dissociative attachment of electrons to CF_2Cl_2 molecules [9]. Radiation of excimer molecules was observed in the immediate afterglow of the transverse space discharge. The radiation intensity in the visible spectral region was lower by approximately two orders of magnitude, compared to the UV region. The basic characteristics of the multiwave excimer emitter (in $He/Kr/Xe/CF_2Cl_2$ and $He/Kr/CF_2Cl_2$, $He/Xe/CF_2Cl_2$ mixtures) are as follows: 222/249/258/308/353 nm; total power of UV radiation ≤5 kW; pulse duration 200-400 ns; pulse repetition rate 1–10 Hz; service life of the gas mixture $\geq(2\text{–}3)\times10^4$ pulses; the working media are $He/Kr(Xe)/CF_2Cl_2$ and $He/Kr/CF_2Cl_2$, at a pressure of 10-40 kPa; and the optimum ratio between the concentrations of Kr and Xe atoms in the four-component mixture is (3–8) / (0.2–0.4) kPa.

5. Conclusions

Thus, the study of the conditions for the simultaneous formation of rare-gas chlorides, fluorides and Cl_2^* TVD-plasma formed from an Ar/Cl_2, $Ar/Kr/Xe/Cl_2$, Ar/CF_2Cl_2 and $He/Kr/Xe/CF_2Cl_2$ mixtures showed that it is a multiwave source of radiation based on the band systems with λ=175/258 nm; 175/222/236/258/308 nm; 175/193 nm and 222/249/258/308/353 nm.

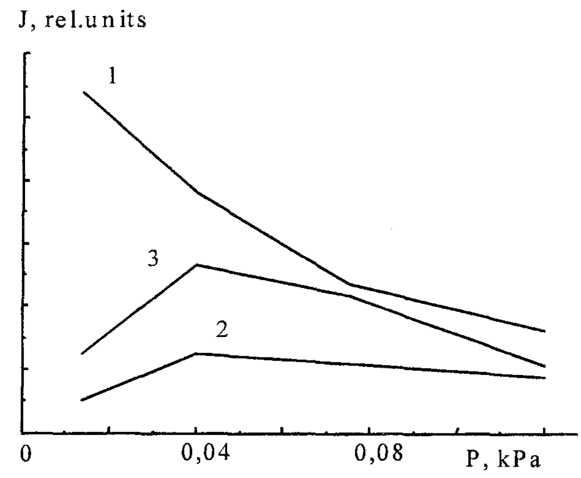

Fig. 5. Dependences of emission brightness of the bands with λ=175 nm ArCl (1), 193 nm ArF (2) and 258nm Cl_2^*(3) upon the composition of freon-12 molecule in TVD on mixture Ar/CF_2Cl_2 by P_{Ar}=12 kPa and U_{ch}=10 kV.

References

1. Yu.G.Basov, *Pump Sources for Microsecond-Pulse Lasers* (Energoatomizdat, Moscow, 1990) [in Russian].
2. H.Kumagai, M.Obara, *IEEE Trans. Plasma Sci.* **16**, 453 (1988).
3. A.K.Shuaibov, *Quantum Electron.* **29**, 127 (1999).
4. A.K.Shuaibov, L.L.Shimon, I.V.Shevera., A.I.Minja, *J. Phys. Studies* **3**, 157 (1999).
5. M.R.Flannery, In: *Gas Lasers,* Ed. by E.W.Mc.Daniel and W.L.Nighan (Academic Press, New York, 1982) p. 177–215.
6. L.G.Piper, D.W.Setser, *J. Chem. Phys.* **63**, 5018 (1975).
7. C.H.Chen, J.P.Judish, M.G.Payne, *J. Phys. B* **11**, 2189 (1978).
8. A.K.Shuaibov, A.I.Dashchenko, Y.N.Semenyuk, *J. Appl. Spectr.* **67**, 399 (2000).
9. A.K.Shuaibov, L.L.Shimon, I.V.Shevera, *Instrum. and Experiment. Techniques* **41**, 427 (1998).

ДОСЛІДЖЕННЯ УМОВ РОБОТИ ТА ХАРАКТЕРИСТИК БАГАТОХВИЛЬОВОГО ВИПРОМІНЮВАЧА НА ХЛОРИДАХ ТА ФТОРИДАХ ІНЕРТНИХ ГАЗІВ

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Подано результати розробки та систематичних досліджень спектральних, часових та ресурсних характеристик електророзрядних ексимерних ламп, що випромінюють на 175 нм ArCl(B-X) / 222 нм KrCl(B-X) / 236 нм XeCl(D-X) / 258 нм Cl_2 (D'-A') / 308 нм XeCl (B-X); 175 нм ArCl(B-X) / 193 нм ArF(B-X); 222 нм KrCl / 249 нм KrF / 258 нм $Cl_2{}^*$ / 308 XeCl / 353 нм XeF. Активне середовище лампи було сформовано на основі газових сумішей : $Ar/Kr/Xe/Cl_2$, Ar/CF_2Cl_2 , $He/Kr/Xe/CF_2Cl_2$, які збуджувались за допомогою поперечного розряду з іскровою перейонізацією. Оптимальний тиск суміші $Ar/Kr/Xe/Cl_2$ складав 15-20 кПа, парціальний тиск хлору був рівним 0.2-0.4 кПа. Для одержання приблизно рівних за величиною яскравостей смуг випромінювання парціальний тиск Kr та Xe повинен бути в межах 0.2–0.5 кПа.

При використанні молекул CF_2Cl_2 як єдиного носія атомів Cl та F було реалізовано багатохвильовий ексимерний випромінювач зі співвідношенням яскравостей хлоридів Kr та Xe до відповідних фторидних молекул як 9/1. Оптимальна концентрація молекул CF_2Cl_2 була рівною 0.008-0.01 кПа (суміш Ar/CF_2Cl_2). Співвідношення між яскравостями B-X смуг молекул ArCl та ArF дорівнювало 10. Ресурс роботи багатохвильового випромінювача становив 5×10^3–1×10^5 імпульсів. Данний випромінювач може використовуватися в імпульсній фотометрії, хімії високих енергій, біології та медицині.