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Optical characteristics and parameters of DBD plasma based on multicomponent mixtures of mercury dibromide vapor with gases

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Optical characteristics and parameters of dielectric-barrier discharge (DBD) plasma in multicomponent mixtures of mercury dibromide vapor with gases have been studied for determination of regularities occurring in plasma, as well as finding the ways of creation the efficient exciplex sources of radiation. Maximum average radiant power and maximum efficiency have been achieved for $HgBr_2/SF_6/N_2/He$=0.1/0.07/4/117 kPa mixture under pulse-periodic discharge excitation mode at pulse repetition frequency 6 kHz and are equal to 48.8 mW and 6.4%. Simultaneous radiation of XeBr* (λ_{max} = 281 nm) and HgBr* (λ_{max} = 502 nm) exciplex molecules have been observed in $HgBr_2$/Xe/Kr==0.3/8/92 kPa mixture under sinusoidal excitation mode at pulse repetition frequency 120 kHz.

Diagnostics of optical characteristics and DBD plasma parameters has been carried out in multicomponent gas mixtures containing mercury dibromide vapor, helium, nitrogen, sulfur hexafluoride, xenon and krypton. Plasma was created in a small-sized cylindrical device (radiation volume ~ 1 cm^3) by means of one-barrier dielectric discharge under pulse-periodic excitation mode at voltage pulse amplitude 10 kV, pulse duration 400 ns at FWHM, pulse repetition frequency 6 kHz, and sinusoidal excitation mode at voltage pulse amplitude 4.5 kV, pulse repetition rate 120 kHz.

Molecular band of electronic-vibrational $B^2\Sigma^+_{1/2} \rightarrow X^2\Sigma^+_{1/2}$ transition of exciplex molecule HgBr* with a peak wavelength λ_{max}= 502 nm is clearly seen in Figure 1. This band has been observed for different mixtures of mercury dibromide vapor with gases.

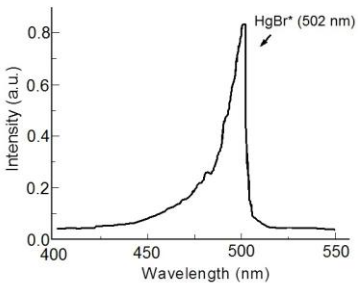

Fig.1: Emission spectrum of DBD in $HgBr_2$/He=0.6/117 kPa mixture at f=6 kHz, voltage amplitude U_a=9 kV.

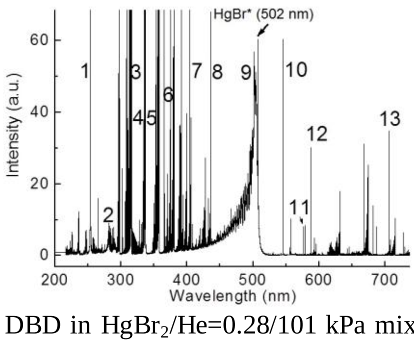

Fig. 2: Emission spectrum of DBD in $HgBr_2$/He=0.28/101 kPa mixture at T=160°C, f=120 kHz, Ua=4.5 kV, where 1 – 254nm Hg, 2 – 281nm XeBr*, 3 – 306nm OH*, 4 – 337nm N_2*, 5 – 357nm N_2*, 6 – 365nm Hg, 7 – 404nm Hg, 8 – 436nm Hg, 9 – 502nm HgBr*, 10 – 546nm Hg, 11 – 578nm Hg, 12 – 589nm He, 13 – 706nm He

Singularities in the emission spectra of the DBD have been observed in $HgBr_2$/He mixture under different excitation modes of the discharge in the studied mixtures. Significantly higher fragmentation of mercury dibromide molecules has been revealed under sinusoidal excitation mode at pulse repetition frequency 120 kHz (see Fig.2).

Figure 3 presents the DBD spectrum in $HgBr_2$ /Xe/ Kr mixture obtained under sinusoidal excitation mode at pulse repetition frequency 120 kHz. Simultaneous emission in visible and ultraviolet spectral ranges of HgBr* (λ_{max} = 502 nm) and XeBr*(λ_{max} = 281 nm) exciplex molecules have been observed.

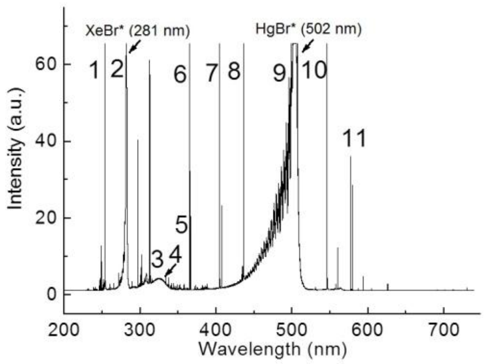

Fig.3: Emission spectrum of DBD in $HgBr_2$/Xe/Kr=0.3/8/92 kPa mixture at T=160°C, f=120 kHz, Ua=4.5 kV, where 1 – 254nm Hg, 2 – 281nm XeBr*, 3 – 306nm OH*, 4 – 320nm XeBr*, 5 – 337nm N2*, 6 – 365nm Hg, 7 – 404nm Hg, 8 – 436nm Hg, 9 – 502nm HgBr*, 10 – 546nm Hg, 11 – 578nm Hg.

Maximum average radiant power 48.8 mW in blue-green spectral range as well as maximum efficiency 6.4% have been obtained in $HgBr_2/SF_6/N_2$/He=0.1/0.07/4/117 kPa mixture (self-heated mode) under pulse-periodic excitation mode at pulse repetition frequency 6 kHz. The mechanism of power increase is the additional population of HgBr* $B^2\Sigma^+_{1/2}$ state due to the quenching of HgBr* ($C^2\Pi_{1/2}$, $D^2\Pi_{3/2}$) upper-energy states by $HgBr_2$, SF_6, N_2 molecules, what has been revealed from studies of DBD plasma parameters.

The main plasma parameters were calculated for the mixture composition corresponding to the maximum efficiency of the emission ($HgBr_2$/He= 0.5/95 %, $HgBr_2/N_2$/He=0.6/3.3/96.1%, $HgBr_2/SF_6$/He=0.68/0.06/99.26 %, $HgBr_2/SF_6/N_2$/He= 0.6/0.2/3.2/96 %, $HgBr_2$/Xe/Kr= 0.28/7.98 /91.74 %).Electron energy distribution function has been calculated by solving the Bolzmann equation in two-term approximation with the help of BOLSIG+ code [1]. In the integral of the electron collisions with mercury dibromide molecules, the processes of excitation of electronic-vibrational states of $HgBr_2$ molecules, dissociative excitation of $X^2\Sigma^+_{1/2}$, $B^2\Sigma^+_{1/2}$ electronic states of HgBr* molecules, excitation of $HgBr_2$ (D) electronic state, attachment and ionization were taken into account. Data on the absolute values of cross sections of these processes, as well as their dependences on the electron energies were taken from [2,3]. The calculations were made for reduced electric field values E/N=1-100 Td, where E – the electric field, N – total concentration of mixtures components. Finally, the electron mobility (μ), mean electron energy (ε), rates of the most important processes (k), energy branching (η) have been obtained. In addition, electron concentrations (N_e) and temperatures (T_e) have been defined on the bases of the calculated plasma parameters. For $HgBr_2/SF_6/N_2$/He mixture they are in the ranges: $\mu = (4.5\ 10^{24}\ N_e - 2.0\ 10^{24}\ N_e)$ 1/m/V/s, ε =(0.5-10.1) eV, k= $(1.0 \cdot 10^{-15} - 1.2 \cdot 10^{-13})$ m^3/s, η= (10 - 36)%, $N_e = (3.7 - 8) \cdot 10^{17}\ m^{-3}$, T_e= (5800 - 117160) K.

References

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