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He study of the excimer intensity radiation in dielectric barrier discharge of Xe/I_2 mixture at high pressure

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Excimer is an acronym for the excited dimmer, molecule which does not exist in the ground state but only in an excited state and thus present a quickly dissociating de-excitation to lower unstable molecular levels. This paper presents the results of a XeI^* excimer radiation intensity study in a dielectric barrier discharge (DBD) at high pressure. The excimer radiation with the wavelengths λ=253.5 nm is found to be the most intense. The dependence curve of the excimer radiation intensity has an optimum for a certain value of the gas mixture total pressure due to the antagonist mechanisms of reaction involved in the generation of the excimer radiation. Also it was found an optimum value of the excimer radiation intensity as a function of iodine percentage.

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1. Introduction

Halogen – rare gas discharges can easily generate excimer radiation. A molecular band is emitted at the transition from the upper excited molecular state to the lower level of the non-excited unstable molecule. At high pressures (20 Torr to few hundred Torr), the main reactions which lead to the appearance of the rare-gas-halide excimers are generally accepted to be either the "harpoon" reaction or ionic recombination /1/, /2/.

In our previous paper we have studied the excimer radiation in $XeCl^*$ gas mixture /5/. Now we will study the excimer radition in XeI^* gas mixture.

In the Xe/I* system gas mixture the processes at the atomic and molecular level responsible for UV light generation are given by the following equations:

$$Xe_2^* + I_2 \rightarrow XeI\ (B) + Xe + I \quad (1)$$

$$Xe^* + I_2 \rightarrow XeI\ (B) + I \quad \text{(harpoon reaction)} \quad (2)$$

The ionic recombination processes are represented by the following equations:

$$Xe_2^+ + I^- \rightarrow XeI\ (B) + Xe \quad (3)$$

$$Xe^+ + I^- + M \rightarrow XeI\ (B) + M \quad (4)$$

$$Xe_2^+ + I_2^- \rightarrow XeI\ (B) + Xe + I \quad (5)$$

$$Xe^+ + I_2^- \rightarrow Xe\ (B) + I + M \quad (6)$$

where M stands for the third body.

The excimer molecules formed by those two mechanisms are not stable and thus quickly decompose, in a range of time of nanoseconds, by the emission of a UV-photon:

$$XeI^* \rightarrow Xe + I + h\nu\ (UV) \quad (7)$$

The radiation generation processes compete with quenching processes. At high pressures the main mechanism of quenching is represented by the three-body reaction, involving rare-gas atoms that quench the excited rare –gas halides by forming tri-atomic species:

$$XeI^* + 2Xe \rightarrow Xe_2I^* + Xe \quad (8)$$

Typical emission of XeI^* excimer provides an intense narrow-band radiation at λ =253 nm within dielectric barrier discharge.

This spectral line proceeds from the transition $B_{1/2} \rightarrow X_{1/2}$, which is, as a rule, the strongest between the other excimer transitions (Figure 1). In this diagram $X_{1/2}$ represents the ground state and the $B_{1/2}$ the first excited energy state of the rare gas/halogen molecule excimer.

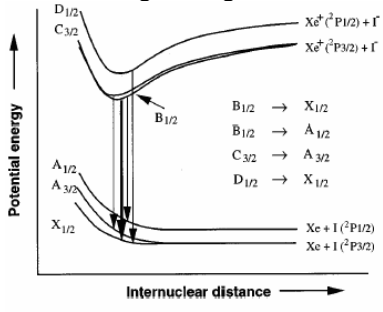

Fig. 1. Diagram of simplified potential energy scheme of xenon-iodine (the width of the arrowed lines indicate relative intensities)

2. Experimental set-up

A classic cylindrical lamp configuration was used in our experiments /3/, /4/. The UV radiation generated was radiating outward the discharge device.

The spectral lamp is composed of two concentric quartz tubes-outer and inner metallic electrodes both made by steel, an external RF high voltage generator, and a system of cooling water. An annular discharge gap from 5 mm length containing the xenon -iodine gas mixture was confined between the two coaxial quartz tubes (Figure 2).

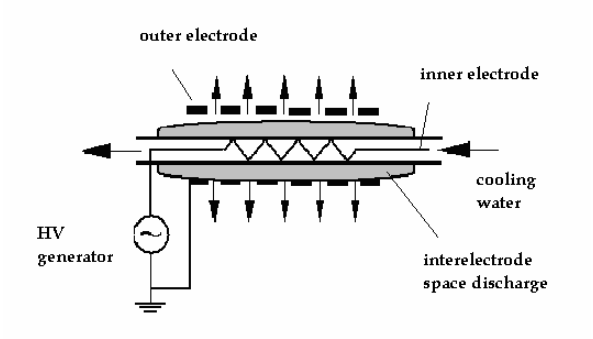

Fig. 2 The experimental set-up.

The outer quartz tube was 30 mm in diameter and had an active length of 75 mm ~defined by the length of the external covering of electrically grounded wire mesh acting as a transparent outer electrode.

A reservoir containing solid iodine crystals was connected to the discharge tube by means of a glass tap. It was selectively heated to produce a vapor pressure of iodine using a little quartz oven. The temperature at which was heated the reservoir quartz was measured with a K-type thermocouple (cromel-alumel).

The total pressure of the xenon– iodine mixtures varied between 20-40 Torr. High purity - xenon and iodine (99.998%) rare gases were used in this experiment.

The discharges were driven by a radio frequency ~RF voltage between 2 and 20 kV in the frequency range of 125–375 kHz. The RF voltage was applied to the inner electrode, while the outer UV mesh transparent electrode was grounded.

In order to record the emission spectra was used an OMA (Optical Multichannel Analyzer), with spectral range between 200-900 nm, resolution 1.5 nm and integration time 0.5-1.0 s.

3. Results and discussion

The measurements were performed using a spectral purity xenon-iodine gas mixture, at a total pressure varying in the range 24.0-39.0 Torr, and the percentage of iodine between 8-40%. The temperature at which was heated the iodine crystals was in the range of 40-80°C corresponding to a range of iodine vapors pressures of 4-15 Torr.

It was measured the dependence of the excimer relative intensity on the percentage of halide gas, namely iodine. The electric ignition voltage of the discharge was around 3kV.

The integration time was 500ms. The spectral relative intensities that appear in the graphs are done in arbitrary units.

In the Figure 3 is presented the dependence of the relative excimer intensity on the iodine percentages (reference spectral line λ=253 nm). Initially the excimer radiation intensity increases with the I_2 pressure up to a maximum value, and then decreases with pressure due to the well known formation of the I_2* excimer (λ=342 nm) at high iodine pressure.

The maximum excimer radiation intensity is reached for an iodine percentage value of 10.7 %.

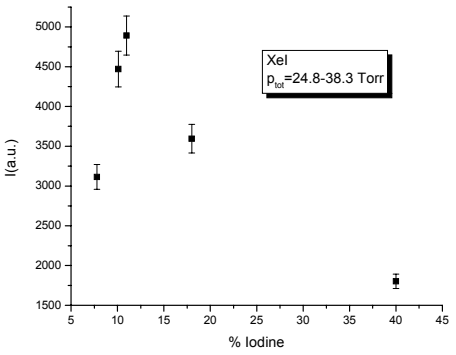

Fig. 3. UV intensity (a.u.) of the XeI excimer as a function of iodine percentages (voltage: 3.3 kV)*

Fig. 4 presents the aspect of the emitted spectra of XeI* gas mixture in a dielectric barrier discharge at different heating temperatures of iodine crystals.

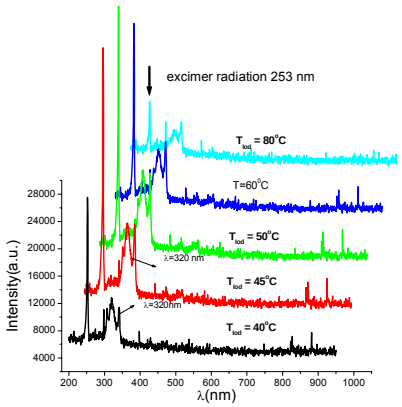

Fig. 4. Spectra of the emitted excimer radiation at different iodine crystals heating temperatures (voltage:3.3 kV)

As it can be observed, after the first spectral peak (λ=253 nm), which is the most intense, appears a second peak (λ=320 nm), which corresponds to the transition

B→A of the xenon-iodine excimer molecule. The intensities of both peaks increase with the increase of temperature and reach an optimum for the temperature of 50^0C.

In Figure 5 is presented separately the dependence of the emitted excimer radiation on the temperature of iodine.

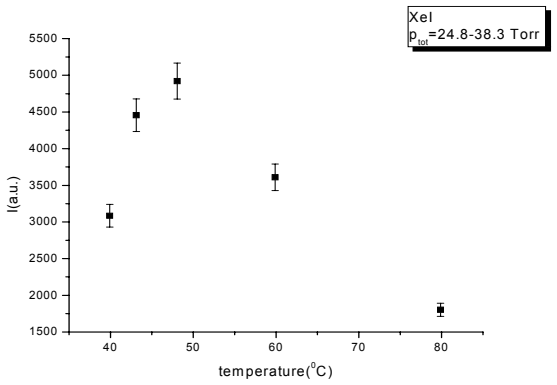

Fig. 5. The dependence of the excimer radiation intensity (a.u.) on the iodine crystals heating temperature (λ=253 nm, voltage:3.3 kV).

In Figure 6 is presented the dependence of the excimer radiation intensity on the total pressure of the gas mixture for the spectral line λ=253 nm.

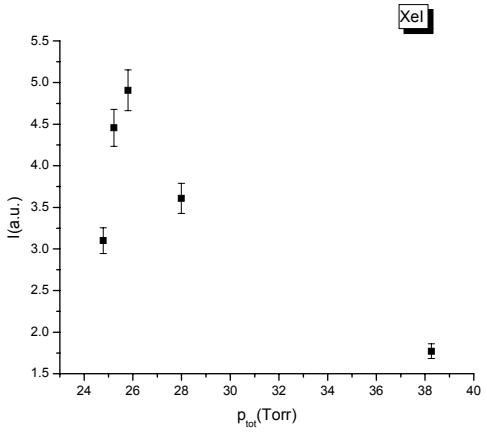

Fig. 6. The dependence of the excimer radiation intensity (a.u.) on the total gas pressure (λ=253 nm, voltage:3.3 kV)

Initially, the excimer radiation intensity increases with the total gas pressure up to a maximum value and then decreases as the gas pressure was further increased. This behavior is due to the fact that the excimer radiation generation at high pressure is a three-body process which increases with the increase of the pressure. After a certain value of the total pressure, this process begins to compete with the quenching process and thus the production of the excimer radiation diminishes.

The maximum value for the excimer radiation intensity in arbitrary units is reached for the total gas pressure of 25.8 Torr.

3. Conclusions

XeI^* excimer excited by a dielectric barrier discharge have been investigated in this paper. The emission spectra were influenced by the total gas pressure and the concentration of iodine gas. At high pressures, the UV intensity emitted by the xenon-iodine excimer plasma decreased due to the appearance of the quenching processes, namely the formation of tri-atomic species such Xe_2I^*.

The use of iodine as added halogen gas in order to generate UV light might offer, in the near future, the possibility to realize a sealed - off cheap UV source.

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