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The M-effect in A.C/D.C. discharges in He+O_2/ Cl_2 gas mixtures

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In a number of previously published papers we reported the possibility of obtaining nearly monochrome radiation spectra using discharges in electronegative-electropositive gas mixtures at pressures in the range 10 –100 torr. This effect of radiation monochromatisation was called by us the M-effect and was related to the heavy particle inelastic collisions. In order to characterize this effect we introduced the M parameter defined as the ratio of the relative intensities of the radiation of two wavelengths of recorded spectra, where one is called dominant radiation, having a spectacular growing at the addition of the electronegative gas and the other one is a common radiation chosen from the spectrum, which is considered the reference line. Using this parameter, various recorded spectra can be compared and thus, the M value will be a measure of the M-effect "intensity". Recorded spectra of a narrow gap (0.15 mm) PDP type discharge in a range of 10-300 Torr in pure He and in (He+O_2/ Cl_2) gas mixtures in A.C and in a D.C. discharge, in this case using an original device, in the same range of pressures and with similar gas mixtures, are presented in this paper. A dramatic change of spectra can be observed.

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1. Introduction

In a number of previously published papers we reported that, on hydrogen addition to neon, reduction of neon emission spectra to practically one line was observed. The wavelength of this line was λ_1=585.3 nm and corresponds to the $2p_1$-$1s_2$ transition /1/-/14/. Due to the fact that the spectra obtained had practically one line, this phenomenon was called ***"the Monochromatisation-effect"(M-effect).***

In order to characterize the "intensity" of this effect, we introduced the M parameter defined as the relative intensity ratio of the increased single line and an arbitrary reference line. For instance, for neon, the two lines are λ_1=585.3 nm and λ_2= 614.3 nm and the M parameter is:

$$M=\frac{I_{\lambda_1=585.3nm}}{I_{\lambda_2=614.3nm}} \qquad (1)$$

In the case of pure neon discharges, the value of the M parameter is of the order of a few units, whereas at 40% hydrogen content in the neon-hydrogen gas mixture, a value as high as 40 was found. These results were obtained for a dielectric barrier discharge in Ne+H_2 mixture at pressures around 10^{+2} torr.

The emission spectrum of a discharge in pure neon is presented in Fig. 1. In Fig. 2, the spectra of (Ne+30%H_2) mixture discharge under identical experimental conditions is shown.

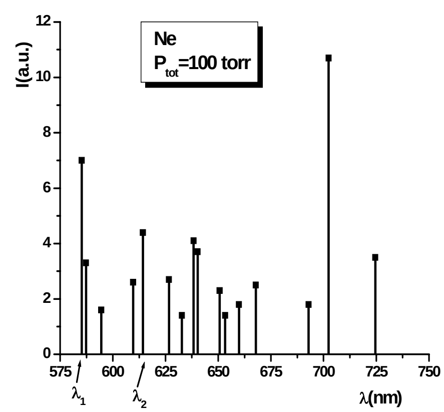

Fig. 1. Recorded spectrum of pure neon PDP discharge (λ_1=585. 3nm, λ_2=614.3 nm).

The M-effect can be observed in various types of discharges. Extensive studies on the M-effect were necessary for explaining it, as can be observed in references /1/-/14/. It can be concluded that two processes are responsible for the appearance of this effect:

1. ion-ion recombination, a process with high cross-section /15 /
2. resonant three body collision reaction of heavy particles (with nearly zero energy defect) [16]-[35].

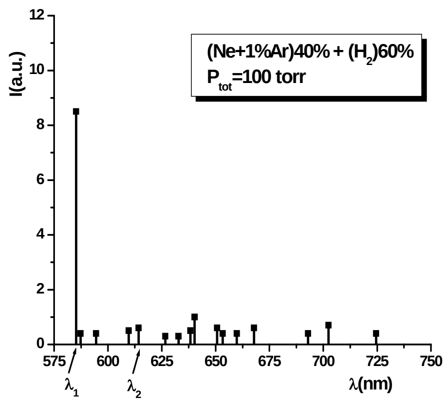

Fig. 2. Recorded spectrum of (Ne+1%Ar)40%+ (H_2)60% gas mixture PDP discharge (λ_1=585.3 nm, λ_2=614.3 nm).

Being observed in various types of discharges and also in various electronegative-electropositive gas mixtures, the M-effect is considered to have a general character /18/-/35/. A number of experimental conditions are necessary in order to obtain the M-effect, namely:

- low gas temperature in order to increase the triple collision reaction cross-section
- elevated pressure of the gas mixture in order to promote triple collisions between heavy particles
- high density of the negative ions. In order to maintain high density of the negative ions, the discharge must be generated in electronegative-electropositive gas mixtures. Low electric field in the plasma and high electron densities can increase the density of negative ions.

In the present paper we report for the first time our results on the M-effect in helium+oxygen/chlorine gas mixtures in A.C and D.C discharges. The peculiarity of the M-effect observed is that, at least in (helium- chlorine) mixture gas, in a PDP discharge it appears a very interesting shift-effect of the spectrum to the range of UV wavelengths.

3. Experimental arrangement

As is concerning the PDP discharge (Plasma Discharge Panel) in A.C. current we used the following experimental arrangement:

Two float glass plates with a thickness of 5mm and the surface size of 300 mm × 50 mm are used to build the discharge device. Each glass plate is covered with a vacuum deposited 1 micrometer thin Al-film linear electrode (see Fig. 1). The length and the width of the electrodes are 190 mm and 4 mm respectively. The electrical connections to the electrodes are on a perpendicular line to the end of each one. The glass surfaces with electrodes are covered with a uniform dielectric layer having a thickness of 18-20 micrometers, except for the surfaces marked in Fig. 1 with black colour. The glass plates are vacuums tight assembled, the discharge space being d ≤ 1 mm.

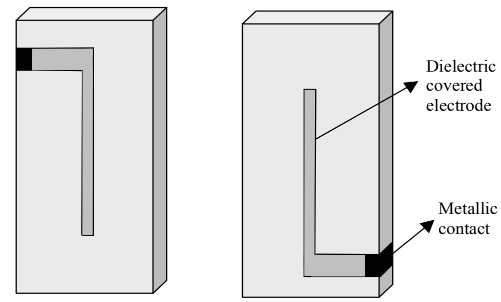

Fig. 3. A view of the deposited thin film electrodes on glass plates.

The linear electrodes are mounted face to face. Polished quartz windows are used to record the emitted UV radiation if there is the case. The discharge is ignited and is maintained using a square wave A.C. - voltage with a frequency in the range of from 10 kHz up to 100 kHz and a peak-to-peak value of the applied voltage of 1 kV. The discharge device is connected to a vacuum pumping unit and can be filled with various gas mixtures at the established pressures. During the measurements, the discharge device remained connected to the pumping unit. A grating spectrometer or an OMA (Optical Multichannel Analyzer) have been used to record the spectra of the emitted radiation.

The experimental set-up used for measurements in D.C discharges was the following (see Fig. 4):

The discharge tube was built from 30 mm diameter Pyrex glass, having a central part from quartz, in order to allow the passage of the UV radiation. The length of this part was of 80 mm and the total length of the tube 160 mm. The two electrodes are made from wolfram Φ 1.5 mm. The top of the electrodes (1-2 mm) are sharp while the rest of them are covered with glass in order to limit the discharges out of the inter-electrodes space. The distance between the two electrodes was 8 mm. The discharge tube was connected to the vacuum pumping unit and can be filled with various gas mixtures at the established pressures. An OMA have been used in order to record the spectra of the emitted light. The ignition electrical voltage was in the range of 1.2 kV to 2.0 kV.

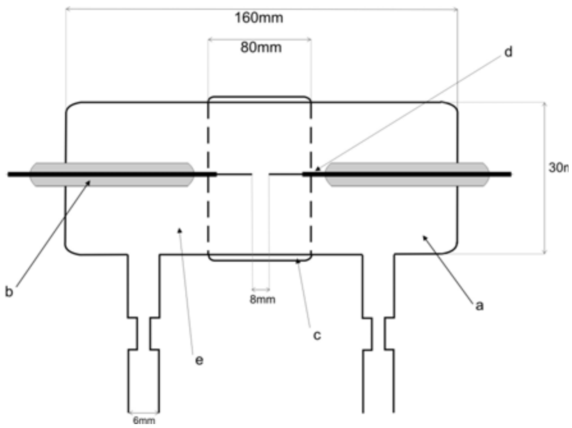

Fig. 4. The experimental set-up for D.C. discharge. a. pyrex discharge tube, b. glass cover, c. wolfram electrodes Φ 1.5 mm, d. Pyrex capillary tubes Φ 6.0 mm.

4. Results

Recorded spectra of a narrow gap (0.15 mm) PDP type discharge at a pressure of 30.25 torr in pure He and also in ($He+O_2/Cl_2$) are presented in Figs. 5, 6, 7, 8, 9, 10 and 11. The percentages of electronegative gases are specified directly on graphs.

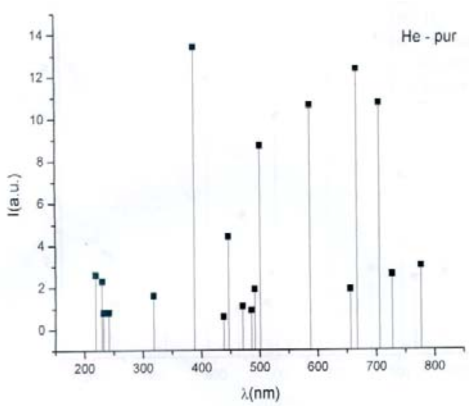

Fig. 5. Emission spectrum of pure helium in a PDP type discharge.

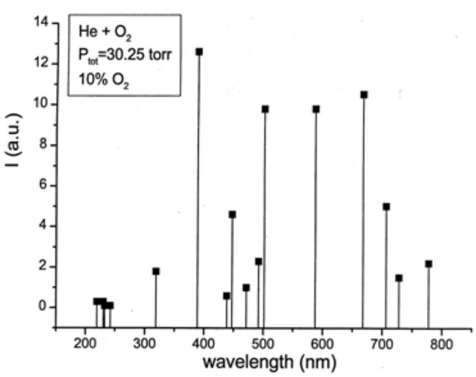

Fig. 6. Emission spectrum of ($He+10\%O_2$) gas mixture in a PDP type discharge.

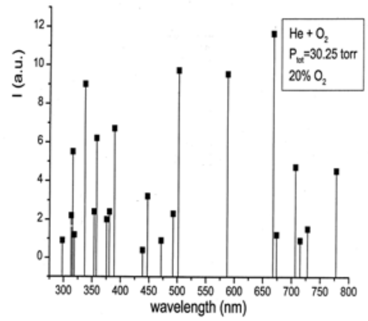

Fig. 7. Emission spectrum of ($He+20\%O_2$) gas mixture in a PDP type discharge.

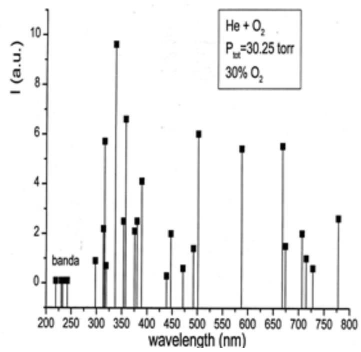

Fig. 8. Emission spectrum of ($He+30\%O_2$) gas mixture in a PDP type discharge.

The dominant spectral line in the case of ($He+O_2$) gas mixture is λ=335.4 nm. As it can be observed, this line has a spectacular growth by rapport of other lines of the registered spectra and the entire spectrum is changing the general aspect, being shifted to the UV wave-lengths.

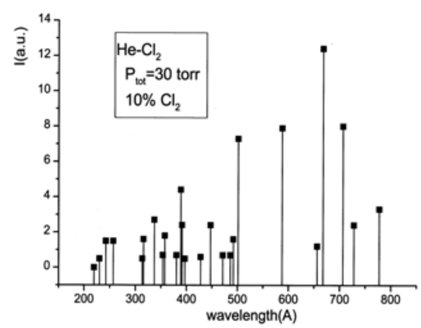

Fig. 9. Emission spectrum of ($He+10\%Cl_2$) gas mixture in a PDP type discharge.

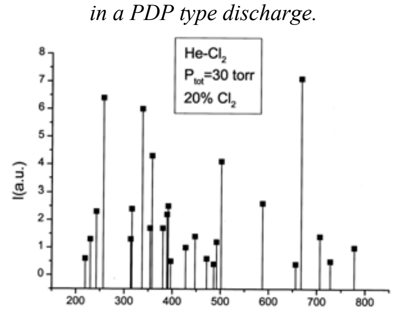

Fig. 10. Emission spectrum of ($He+20\%Cl_2$) gas mixture in a PDP type discharge.

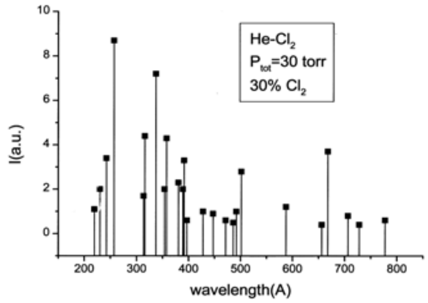

Fig. 11. Emission spectrum of (He+30%Cl_2) gas mixture in a PDP type discharge.

As in the case of (He+O_2) gas mixture, also in the (He+Cl_2) gas mixture we have the dominant line at λ=335.4 nm, having a spectacular growth by rapport of others spectral lines (the reference lines) and the entire spectrum is shifted to the UV wavelengths range.

In the case of a D.C discharge in a (He+O_2) gas mixture, we have obtained the following spectra:

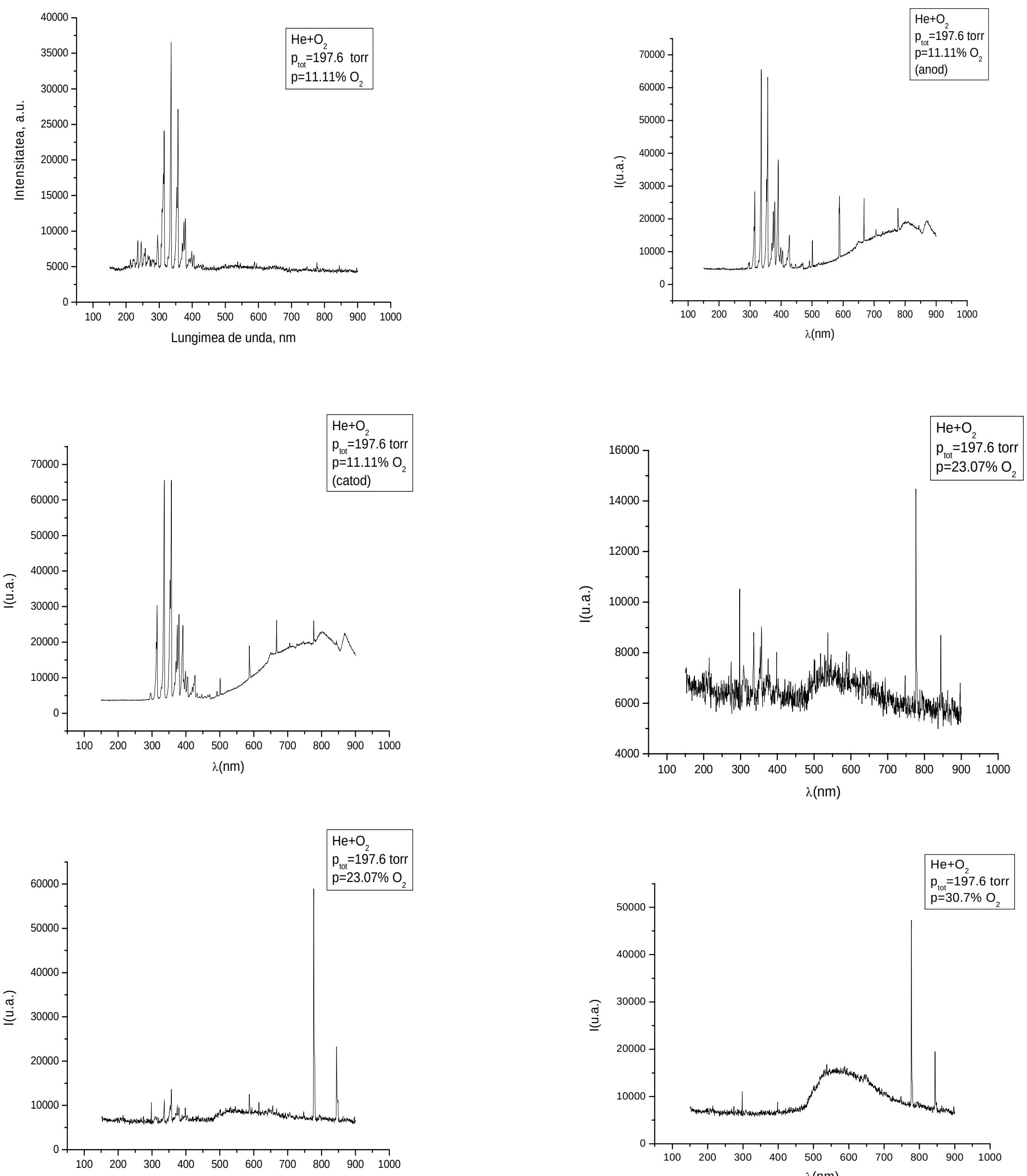

Fig. 12. The emission spectra of a (He+O_2) gas mixture D.C. discharge at a total pressure of 197.6 torr for different percentages of electronegative gase.

In the case of a D.C. discharge in ($He+O_2$) mixture gas, in the chosen experimental geometry, it can be observed the existence of the monochromatisation effect too, but the spectrum is shifted to the IR wavelengths range. The dominant spectral line is λ =781.6 nm.

5. Discussion

The results of over a twenty scientific articles published in the last five years led us at the conclusion that the main process responsible to the M-effect is the positive ion-negative ion recombination (polar) reaction.

A general form of this reaction is given by the following equation:

$$P^+ + N^- + N^* \rightarrow P^* + N^0 + N^* \qquad (2)$$

Where the used symbols are:

P = the electropositive atom
N = the electronegative atom
N^*= the electronegative atom in a metastable state
N^0 = the electronegative atom in the fundamental state

The second condition that must be accomplished for the existence of the M- effect is that the energetic balance of this reaction is zero or, as much as possible, near to zero (resonant reaction).

According to equation (2) the calculation of the wavelengths for which the M-effect appears is possible in different electronegative-electropositive gas mixtures. Due to the energetic condition, we found that in some gas mixtures, e.g. ($Ne+SF_6$) or ($He+H_2$), the M-effect does not appear.

As concerning the spectral shift, the existence of *quenching processes* can be presumed. These processes are responsible for the extinction of some energetic levels, leading to the apparition of this phenomenon. The calculations must be done and will constitute the subject of a future article.

6. Conclusions

The M-effect appears only in electronegative-electropositive gas mixtures. In some mixtures, ($Ne+SF_6$) or ($He+H_2$, the M-effect does not appear due the energetic condition. There are some gas mixtures, as ($He+Cl_2$) and ($He+O_2$), it can be observed the apparition of a spectral shift to the UV wavelengths range. Besides the two mechanisms of reaction, which are already explained, there are some others mechanisms involved in the apparition of the spectral shift, the most probable quenching processes.

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