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PRESSURE DEPENDENCE OF THE DC NITROGEN PINK AFTERGLOW

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Introduction

The nitrogen pink afterglow phenomenon is studied for more than 50 years. Different discharge configurations with DC, MW of RF power sources have been studied up to now [1, 2]. Based on the experimental data, the kinetic models of the post-discharge processes were developed [2, 3], too. But up to now, there was not done any comparative study of pressure and temperature influence on this phenomenon. This study extends our recent experimental works of changes in nitrogen post-discharge kinetics.

Experimental set-up

The DC flowing post-discharge was used for the experimental study. A simplified schematic drawing of the experimental setup is given in Fig. 1.

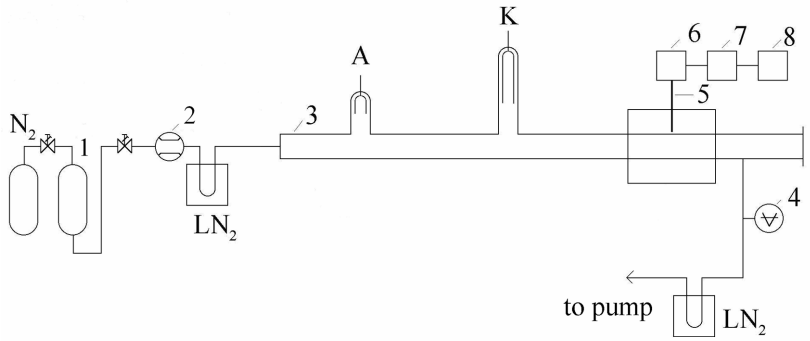

Fig. 1 Scheme of the experimental set up. 1 – catalyzer Oxiclear; 2 – mass flow controller; 3 – Pyrex discharge tube; 4 – capacitance gauge; 5 – quartz optical fiber; 6 – monochromator Jobin Yvon Triax 550; 7 – CCD; 8 – PC.

The active discharge was created in a Pyrex discharge tube with a 120 mm electrode distance and the constant discharge power about 290 W. The total gas pressure was in range 500 Pa up to 5 000 Pa. Hollow molybdenum electrodes were placed in the side arms of the main discharge tube to minimize their sputtering and also to minimize scattering the light emitted in the electrode regions. Nitrogen was of 99.99% purity and it was further cleaned by Oxiclear and LN_2 traps. The reactor system was pumped continuously by a rotary oil pump separated from discharge tube by another LN_2 trap. The gas flow was automatically controlled by mass

flow controller and the total gas pressure in the discharge tube was measured by a capacitance gauge connected to the end of the discharge tube.

The optical spectra in the range of 300 – 850 nm were measured by Jobin Yvon monochromator TRIAX 550 with the 1200 grooves per mm grating coupled with multichannel detector. The emitted light was led to the entrance slit of the monochromator by the multimode quartz optical fiber movable along the discharge tube. The reactor wall temperature was 300 K in first case. In the second case, the optical fiber holder was filled by liquid nitrogen. Thus the reactor wall temperature was kept at 77 K around (± 3 cm) the observation point and it allowed studying the temperature dependence of the post-discharge processes.

Nitrogen 1st positive $(N_2(B\,^3\Pi_g) \rightarrow (A\,^3\Sigma_u^+))$ and 2nd positive $(N_2(C\,^3\Pi_u) \rightarrow (B\,^3\Pi_g))$ and nitrogen 1st negative $(N_2^+(B\,^2\Sigma_u^+) \rightarrow (X\,^2\Sigma_g^+))$ spectral systems were recorded in all spectra. Although the Oxiclear purifier column was used, the bands of NO^{β} system $(NO(B\,^2\Pi) \rightarrow NO(A\,^2\Sigma^+))$ dominantly originating at vibrational level 0 were observed, too, mainly at the higher pressures and later decay times. No other molecular emissions were observed. The relative vibrational populations at the selected nitrogen levels were calculated using all measurable emission band intensities. The transition probabilities and wavelengths of the transitions were taken from *Gilmore's* tables [4].

Results and discussion

Graphs in Fig 2 show dependencies of measured intensity on post-discharge decay time for selected bands. The highest contribution to the pink afterglow intensity is from the 1st negative system.

For wall temperature 300 K at low total gas pressures, the pink afterglow maximum was observed at the decay time about 5 ms and it was very sharp. If the gas pressure is increased, the pink afterglow effect is shifted to the later decay times and the pink afterglow maximum is not such sharp as at the total gas pressure about of 500 Pa. The maximum intensity was observed at pressure in the range 1 000 to 1 500 Pa for nitrogen 1st negative spectral system. Similar dependencies were observed for the other two nitrogen spectral systems, too.

Situation is a little different for wall temperature of 77 K. The maximum pink afterglow intensity is observed for the pressure of about 3 000 Pa for nitrogen 1st negative system. Besides the pink afterglow, there is secondary enhancement of intensity at the later decay time (90 – 110 ms). Absolute value of intensity is lower for all spectral systems in comparison to intensities observed at 300 K wall temperature.

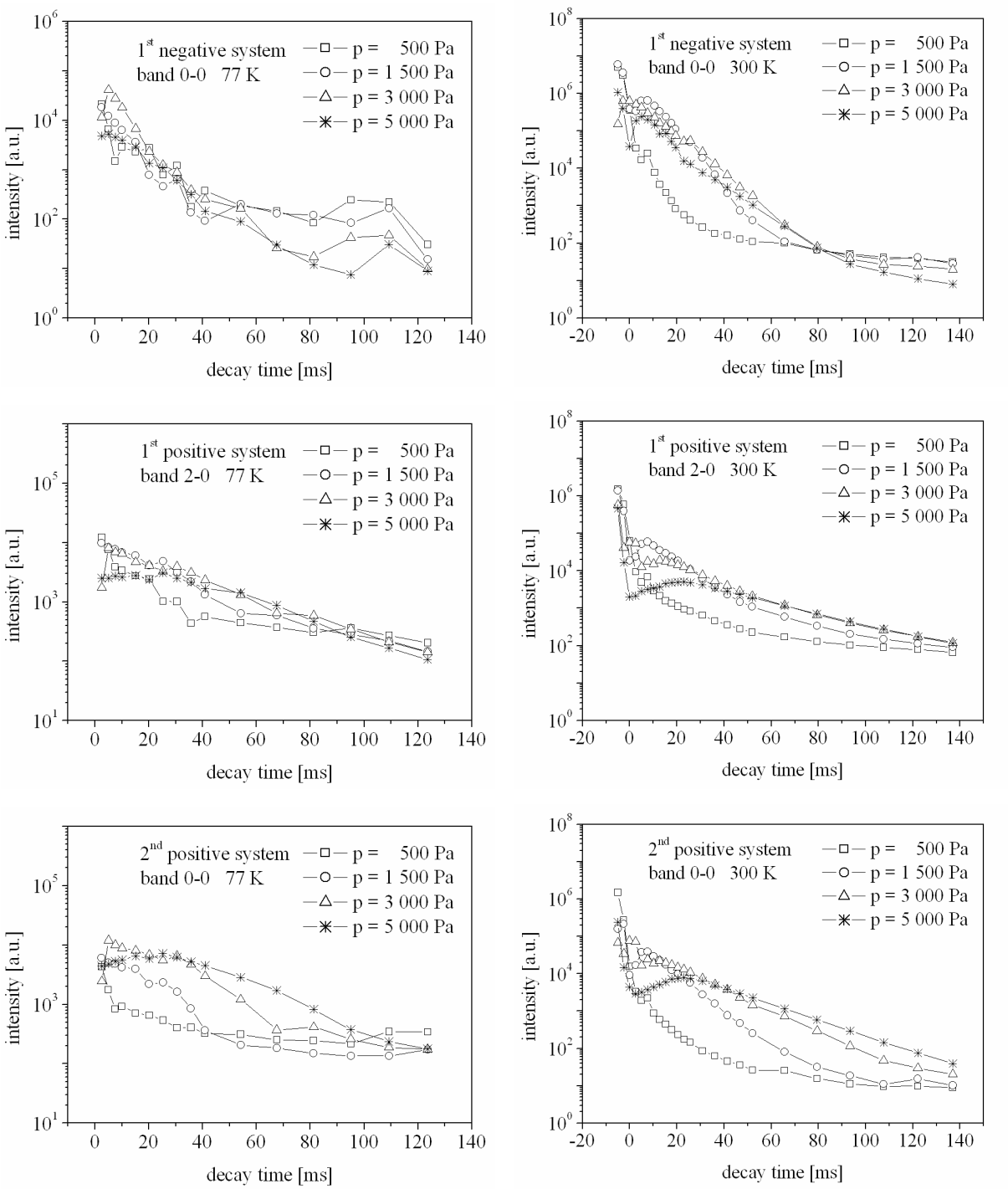

Fig. 2 Dependencies of intensity on decay time for selected bands of spectral systems for different gas pressures and different wall temperatures.

Kinetic model

The post-discharge kinetics starts by v-v process in the ground state that creates highly excited vibrational states. These states are precursors for the pooling reactions populating $N_2(B\ ^3\Pi_g)$ and $N_2(C\ ^3\Pi_u)$ states. The contribution of other electronic metastable states, especially metastable singlet states, to the pink afterglow creation is not fully understood yet. Besides pooling reactions, the atomic nitrogen ground states three body recombination significantly contributes to vibrational populations at levels $N_2(B\ ^3\Pi_g, v = 10 – 12)$. A much more complex description of the mechanisms was described recently in [5].

The kinetics of the molecular ion radiative state can be explained in a two-step scheme. The first step is the molecular ion creation because the charged particles concentration is very low due to the fast electron-ion recombination at the post-discharge beginning. This process is known as a step-wise ionization. In its principle, the highly excited neutral metastable molecules (excited both electronically and vibrationally) can have energy sufficient for the ionization during their mutual collisions. After molecular ion creation, the excitation to the radiative state must be completed. The main process responsible for the population of the radiative $N_2^+(B\ ^2\Sigma_u^+)$ state is the collisionally induced energy transfer from the vibrationally excited neutral ground state molecules, namely $N_2(X\ ^1\Sigma_g^+, v \geq 12)$ [6].

Conclusions

The work presents results obtained during spectroscopic observations of DC flowing post-discharges of pure nitrogen plasma at different total gas pressures and different wall temperatures (77 and 300 K). Three nitrogen spectral systems and NO^β bands were identified in the investigated spectral region. The pink afterglow effect was observed at all applied total gas pressures. With the increase of total gas pressure, it shifts to the later decay times (up to 20 ms). Based on the experimental results, the simplified kinetic model was proposed.

Acknowledgement

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References

[1] J. F. Pierson, T. Belmonte , H. Michel: Appl. Surf. Sci. **172**, 285, (2001).

[2] C. D. Pintassilgo, J. Loureiro, V. Guerra: J. Phys. D: Appl. Phys. **38**, 417, (2005).

[3] V. Guerra , P. A. Sa, J. Loureiro: Europ. Phys. J. – Appl. Phys. **28**, 125, (2004).

[4] F.R. Gilmore, R. R. Laher, P.J. Espy: J. Phys. Chem. Ref. Data **21**, 1005, (1992).

[5] N. Sadeghi, C. Foissac, P. Supiot: J. Phys. D: Appl. Phys. **34**, 1779, (2001).

[6] F. Krcma, E. T. Protasevich: Post-discharges in Pure Nitrogen and in Nitrogen Containing Halogenated Hydrocarbons Traces, Tomsk Polytechnic University Publishing, Tomsk 2003.