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THE IMPORTANCE OF DISCHARGE CURRENT IN THE FORMATION OF THE PINK AFTERGLOW OF A NITROGEN DC DISCHARGE

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Introduction:

The study of nitrogen discharges and afterglows is a rather complex problem, as a consequence of the strong interplay between different kinetics. In order to refine the kinetic description of nitrogen plasmas, the available models should be continuously put to test in different conditions.

Experiment:

In this work we have used optical emission spectroscopy to measure the (2-0) 1st positive system emission in nitrogen DC discharge at pressure p = 1000 Pa for discharge currents in the range 50-200 mA in a Pyrex tube with internal diameter of 13 mm.

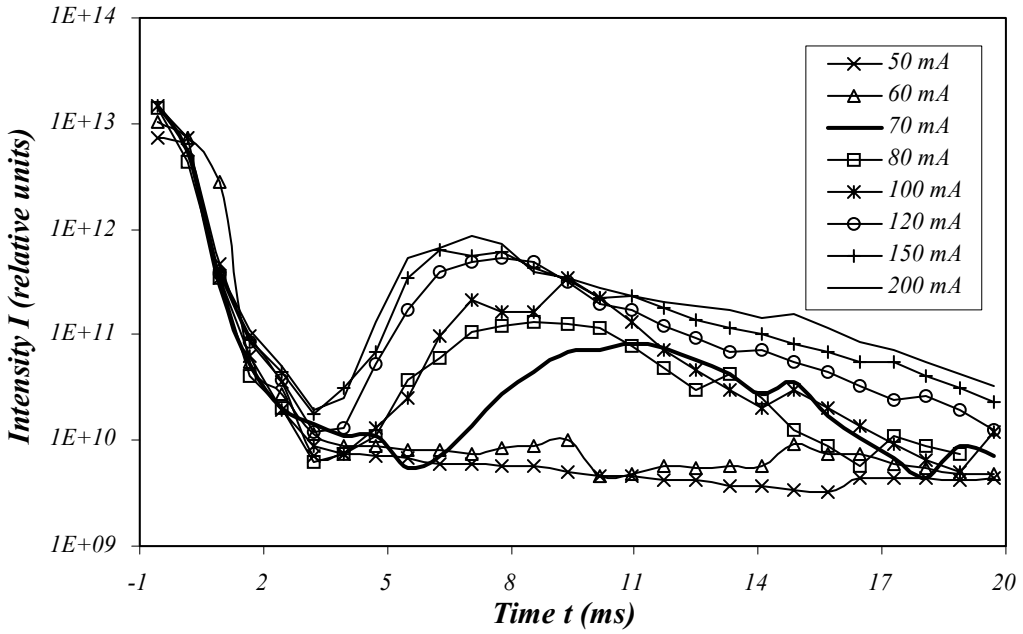

Figure 1: Time evolution of the 1st positive system (2-0) band intensity in the post-discharge, for currents: 50; 60; 70; 80; 100; 120; 150 and 200 mA.

Figures 1 and 2 show that an important difference in behaviour occurs when the discharge current I is increased from 60 to 70 mA. As a matter of fact, at 50 and 60 mA the pink-afterglow, characterized by the raise in the optical emission after a dark zone just after the active discharge, does not exist, only the well known yellow-afterglow being visible. The former is a result of the vibration-vibration (V-V) up-pumping followed by vibration-to-electronic (V-E) energy exchanges [1], whereas the latter is a result of 3-body N-atom recombination. However, for 70 mA and higher currents the pink-afterglow appears and gets more noticeable as the current increases. The effect is easily seen at naked eye, the afterglow color changing from yellow to pink. Moreover, the maxima of optical emission intensities are displaced to shorter afterglow times as current increases.

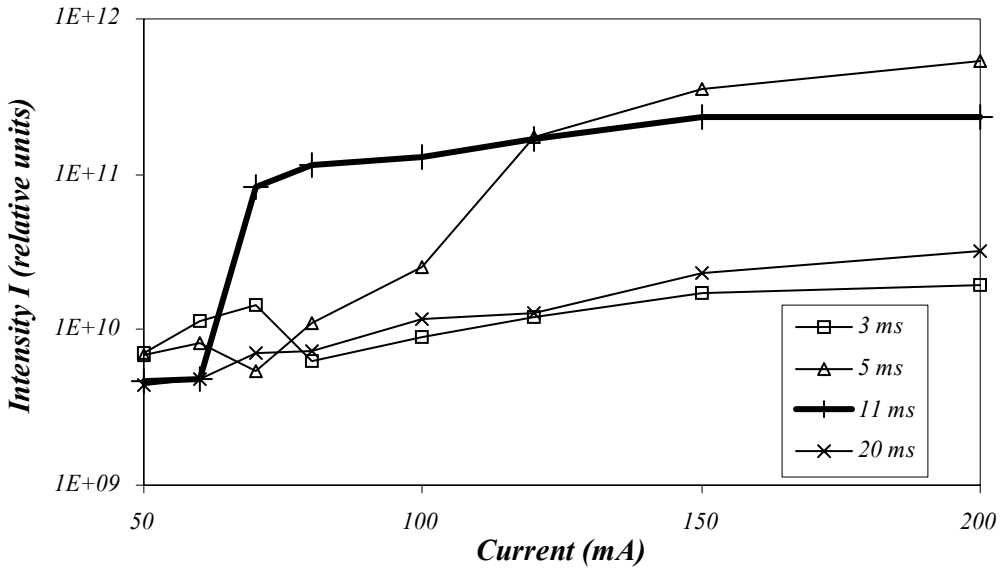

Figure 2: Emission intensity of the 1st positive system (2-0) as a function of current, for different times in the post-discharge: 3; 5; 11; 20 ms.

Theory and modeling:

The model developed in [1] was used to study and interpret this effect. The calculations were performed for a fixed gas temperature both in the discharge (T_{gd}) and in the afterglow (T_{ga}). The model predictions do not reveal any significant difference in the optical emissions with current if T_{gd} and T_{ga} are kept constant for all discharge currents, at 500 K and 300 K, respectively, as shown in figure 3.

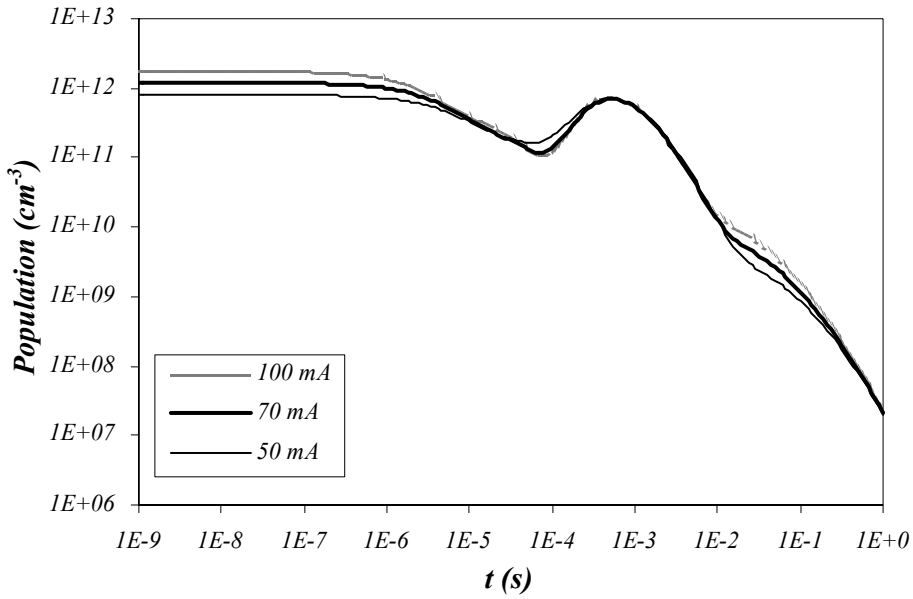

Figure 3: Time evolution of $N_2(B)$ population in the post-discharge for currents of 50; 70; 100 mA. Gas temperature: in the active discharge, T_{gd} = 500 K; in the afterglow, T_{ga} = 300 K.

Strikingly, the theoretical calculations indicate that the pink-afterglow disappears if $T_{gd} \approx T_{ga}$, being more pronounced as the difference between T_{gd} and T_{ga} increases. This can be seen in figure 4, where T_{gd} was kept constant and equal to 1000 K, whereas T_{ga} was set to 300, 500 and 1000 K. Notice as well the displacement of the emission maxima to earlier times as the difference between T_{gd} and T_{ga} increases. This is due to the changes induced in the V-V and V-T relaxation mechanisms by the gas temperature and is consistent with the experimental observations, as an higher discharge current corresponds to an higher value of T_{gd}.

Figure 5 depicts the self-consistent calculations for I = 50 and 70 mA, assuming T_{ga} = 500 K and T_{gd} increasing from 500 to 1000 K. The results are in qualitative agreement with the experimental measurements from figure 1, confirming the importance of gas temperature in the explanation of the phenomenon. Nevertheless, the calculations yield the maximum of the afterglow emission at earlier times than observed experimentally. This can be due the sudden jump in the temperature considered in model (T_{gd} to T_{ga}). Work is in progress to include a realistic temperature profile in the afterglow and to further characterize this phenomenon.

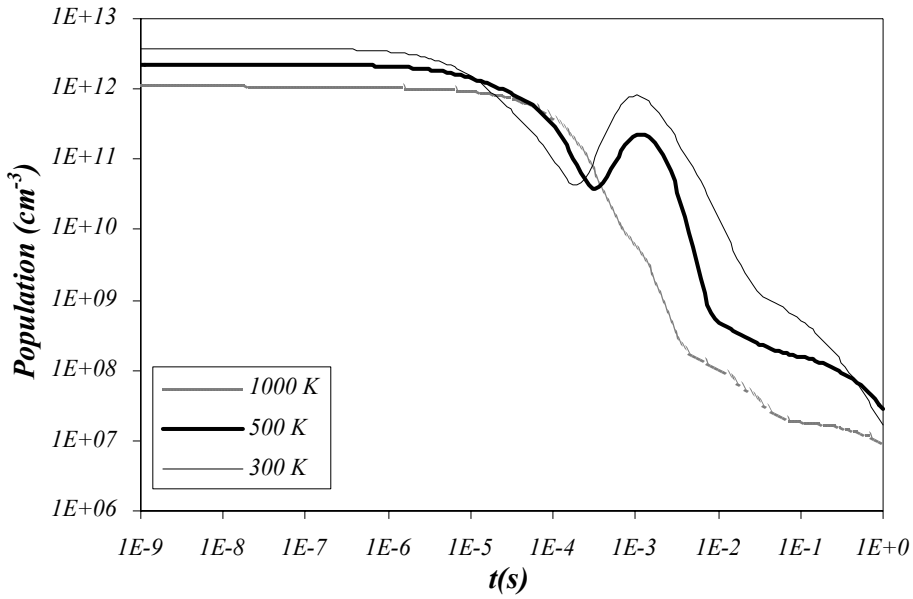

Figure 4: Time evolution of $N_2(B)$ in the post-discharge, for I = 70 mA and T_{gd} =1000 K. T_{ga} = 300, 500 and 1000 K.

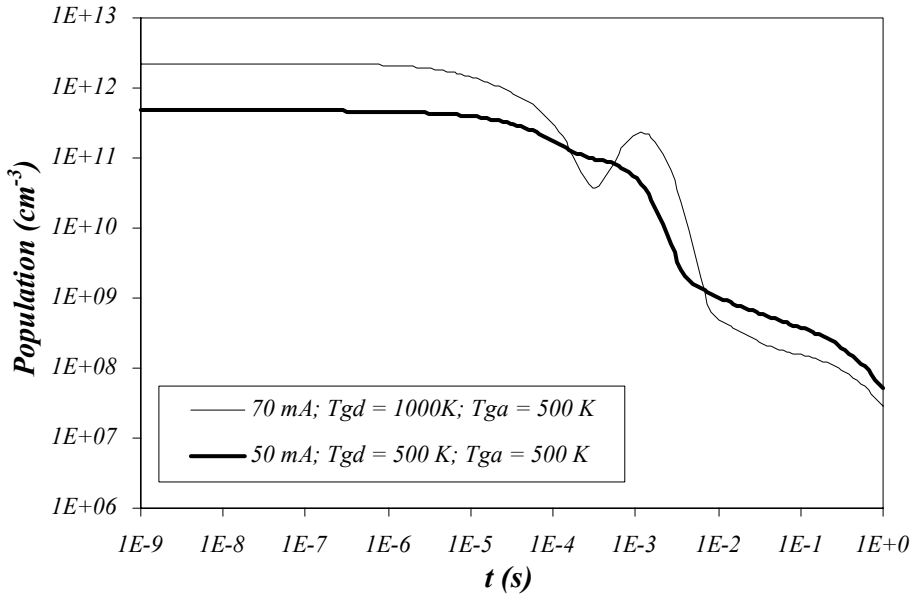

Figure 5: The same as in figure 4, but for T_{gd} *= 1000 K (for 70 mA) and 500 K (for 50 mA) and* T_{ga} *= 500 K (for 50 and 70 mA).*

References:

[1] P.A. Sá, V. Guerra, J. Loureiro, N. Sadeghi, J. Phys. D: Appl. Phys. 37, 221 (2004)