Topic number: 5

Evolution of Molecular Ion Rotational Temperature in Nitrogen Afterglow with Respect to Discharge Current

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The post-discharge phenomena are subjects of many studies during more than last 50 years. Various spectroscopic methods [1, 2] as well as Langmuire probe measurements [3] are commonly used in experimental works; the numeric models [4] were created during the last two decades based on these experimental data. All kinetic processes are determined by reaction coefficients that are temperature dependent. For right understanding of processes in plasma, knowledge of temperature evolution in plasma is necessary. Temperature determination is usually based on the assumption of local thermodynamic equilibrium (LTE) conditions. The rotational temperature is equal to the neutral gas temperature at these conditions. But the existence of LTE conditions should be rather disputable at post-discharge conditions. This contribution clearly demonstrates this fact.

We measured rotational temperature evolution of molecular ion in flowing nitrogen discharge and post-discharge up to decay time of 50 ms. Pure nitrogen (>99.9999%) flowed in Pyrex or Quartz tubes with internal diameter of 13 mm with velocity of about 10 m/s at pressure of 1000 Pa. The DC discharge current was varied between 45 and 200 mA, discharge voltage of 1.4 kV was more or less current independent. Optical emission spectra of the nitrogen 1[st] negative system were recorded using TRIAX 550 spectrometer with 3600 gr/mm grating.

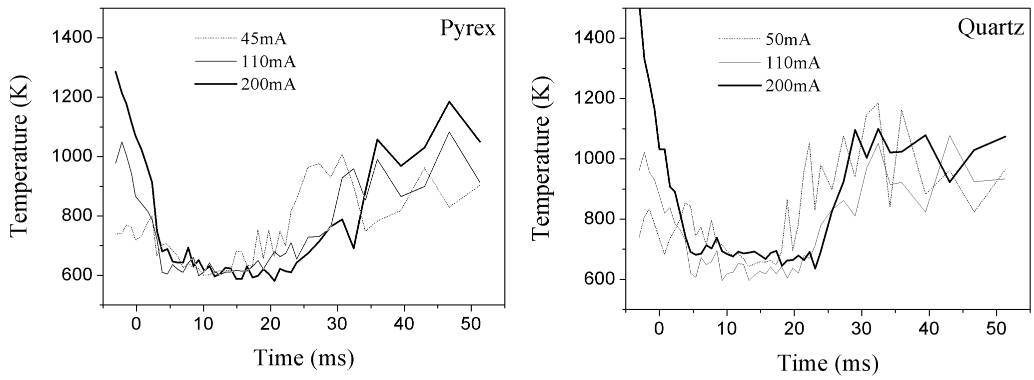

Fig. 1: Rotational temperature time evolution during post-discharge at selected discharge currents.

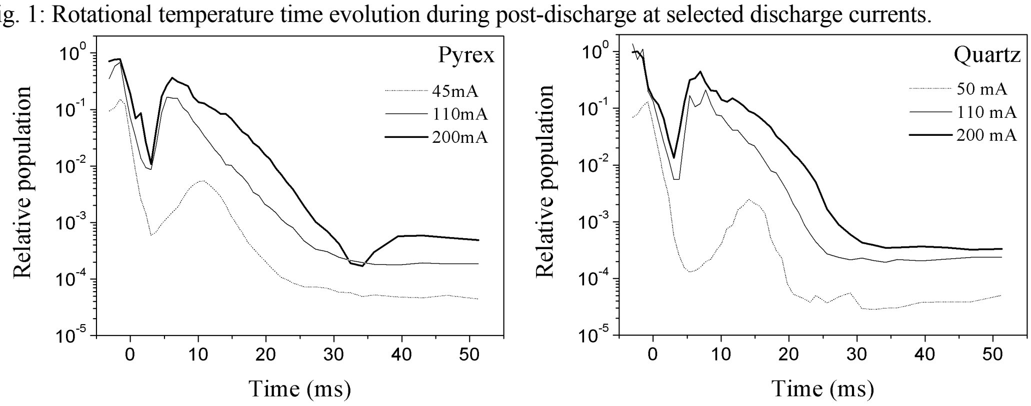

Fig. 2: Time evolution of nitrogen 1[st] negative 0-0 band head during post-discharge.

The rotational temperature evaluation during the post-discharge is shown in Fig. 1. Three different regions can be seen: temperature is decreasing down to about 650 K during the first 5 ms of the post-discharge, later it is more or less constant (up to about 20 ms). Temperature in these two parts is independent on the wall material but in later post-discharge it is dependent on reactor walls. The temperature rapidly increases up to about 1000 K in Quartz tube within 5 ms and later it is nearly time independent. The same temperature increase is observed also in Pyrex tube but it is significantly slower and 1000 K is reached at the end of our time interval (50 ms). Position of this temperature increasing part depends on the applied discharge power; the decay time of the temperature increase beginning is directly proportional to the applied power.

We suppose that the observed temperature dependences during the post-discharge reflect different mechanisms of the molecular ion creation. To confirm this statement, we added the N_2^+ (B,v=0) state population profiles during the afterglow. The relative populations are nearly independent on the wall material but they are strongly dependent on the applied discharge power. The nitrogen pink afterglow effect (enhancement of the molecular ion population during the post-discharge) is well visible at all applied powers but the maximum of this effect shifts to shorter decay times with the increase of applied power. The population profiles during afterglow show at least two different processes after the pink afterglow maximum. The population during the first part can be characterized by the exponential decay but the second part is nearly time independent.

The relation between rotational temperature and relative population is the most interesting result. The end point of initial temperature decrease well corresponds to the population minimum between an active discharge and pink afterglow effect. The beginning of the temperature increase at the later decay times corresponds to the beginning of the constant population part during the post-discharge. By other words, the rotational temperature of nitrogen molecular ion is significantly lower during the pink afterglow effect with respect to the other parts of post-discharge.

The accuracy of the experimental results is of about 5% at decay times when relative population is high and decreases down to 15% at the latest decay times. The observed phenomena are significantly higher than these accuracy limits.

Our experimental results can help to recognize different processes creating excited nitrogen molecular ionic states during the post-discharge. The detailed analysis of the experimental results will include the temperature evaluation during the post-discharge determined by other spectral systems and later the detailed modeling of the kinetic processes.

Acknowledgement

This work was supported by Czech Science Foundation, contracts No. 202/08/1106 and 202/09/H080.

Reference

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