Influence of Pressure on Relative Populations of Vibrational Levels of the N_2 (C $^3\Pi_u$) State of Nitrogen for Electron Beam Excitation

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Excitation of molecular nitrogen by electron beams or electrical discharges leads to strong light emission on N_2 C $^3\Pi_u \rightarrow$ B $^3\Pi_g$ transitions, the so called second positive system (SPS). Excitation mechanisms which populate vibrational levels of the C $^3\Pi_u$ state in addition to electron impact excitation received very little attention. The existence of strong vibrational relaxation within the C $^3\Pi_u$ state due to collisions with ground state N_2 is claimed in two papers [1,2], while it was found in Ref. [3] that the vibrational relaxation is very weak.

We have investigated the presence of extra excitation mechanisms by measuring the pressure dependence (10 - 1400 hPa) of the ratio of photon fluxes for vibrational levels 0 and 1 and time evolution of the SPS emission. Excitation of nitrogen was performed with low energy (12 keV) electron beams (dc and pulsed), which enter the target gas through a 300 nm thick silicium nitride foil [4].

Our experiments show that when nitrogen is excited with 5 ns electron beam pulses, there is a noticeable difference in the time evolution of emission from vibrational levels 0 and 1 in the early phase of the decay (Fig. 1). Note that for v'=1 the decay becomes exponential already 5 ns after the end of a 5 ns excitation pulse, while the v'=0 decay shows an exponential behaviour only after about 25 ns. This fact indicatates that the vibrational levels of the C $^3\Pi_u$ state (at least v'=0) are populated not only by direct electron impact excitation.

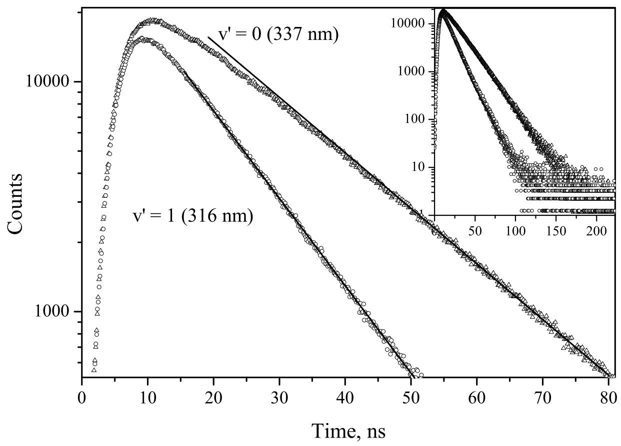

Fig. 1: Time evolution of the light emission from 100 hPa N_2. The insert shows the full time range, while the main graph demonstrates the nonexponential character of the v'=0 emission in the early phase of the decay.

The ratio of photon fluxes F_{02}/F_{13} for the bands at 380.6 and 375.6 nm is shown in Fig. 2. The fluxes were derived by integrating the photon count rate over the whole wavelength range of each band for different experimental conditions (see Fig. 2 caption). As a cross-check of the experimental procedure and the validity of A_{ij} values, a synthetic flux ratio F_{02}/F_{13} was calculated using experimental data for the F_{01}/F_{12} ratio and taking the corresponding A_{ij} values. The result is shown in Fig. 2 with star-shaped dots.

The flux data presented in Fig. 2 are compared with predictions made by a model, where we assume that the only excitation mechanism populating the C $^3\Pi_u$ state is direct electron excitation. The solid and short-dashed lines in Fig. 2 show the results of the calculation using the quenching rate constants from the present work and from Ref. [3], respectively.

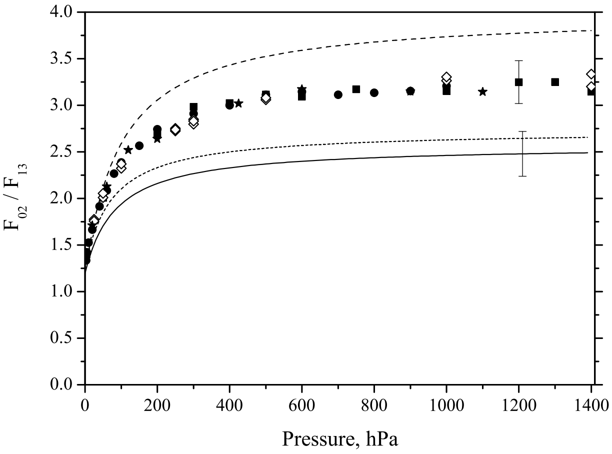

Fig. 2: Ratio of photon fluxes recorded from the 0→2 and 1→3 transitions for 5 μA dc current (full dots), 10 μA dc current (full squares) and 200 ns pulsed operation (open diamonds). The results of calculations are shown with lines lines (see text).

Comparison of the experimental data with the predictions of the model (solid line in Fig. 2) shows a considerable difference between the experimental flux ratios and the ratios predicted by the model. This fact confirms the presence of an excitation mechanism which populates C $^3\Pi_u$ vibrational levels in addition to direct electron impact excitation. This mechanism might be vibrational relaxation as described in Ref. [2] which predicts an even larger increase of the flux ratio with pressure (see long-dashed curve in Fig. 2). However, large uncertainties in the relaxation and quenching rate constants [2] forbid a quantitative comparison of such calculations with the experimental data.

A comparison of our flux data with the results of Ref. [1] have shown that extra population channels due to quenching of higher electronic states cannot be excluded, in contrast to the conclusion made in Ref. [1]. The results presented in this report are published in Ref. [5].

References

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