Relaxation of electronic excitation in nitrogen discharge plasma at high specific deposited energy

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The energy relaxation from electronic degrees of freedom of molecular nitrogen excited by a capillary nanosecond discharge at high specific deposited energy and electric fields of 200-300 Td is investigated experimentally and numerically. The key role of pooling reaction between metastable $N_2(A^3\Sigma_u)$ states and quenching of $N(^2D)$ atoms by N_2 in the mechanism of fast gas heating at high specific deposited energy is demonstrated. The temperature dependence of pooling reaction rate constant was obtained based on the treatment of available experimental data.

1. Introduction

The knowledge of the channels of energy relaxation from electronically excited states is extremely important for the applications. This study is dedicated to the experimental and numerical study of the relaxation of electronic excitation and fast gas heating in pure nitrogen, excited by capillary nanosecond discharge at electric fields of E/N = 200-300 Td and specific deposited energy up to 1 eV/molecule.

2. Experiment setup

The nanosecond discharge was initiated in the capillary tube 1.5 mm of internal diameter and 70 mm in length, P = 27 mbar. High-voltage pulses of U = + 9.3 kV, 30 ns FWHM were used to initiate the discharge. For each initial pulse from the generator, typically three pulses with progressively attenuated amplitude separated by 250 ns were observed. A detailed description of the experimental setup and diagnostic techniques are presented in [1].

3. Results and discussion

The temporal evolution of gas temperature in nitrogen, excited by capillary nanosecond discharge, measured experimentally and compared with the one calculated numerically in 1-D axially symmetric model is presented in Fig. 1. The calculations were performed according to the model described in [1,2].

The observed fast increase of gas temperature in nitrogen (2200 K/μs, Fig. 1) demonstrates fast energy relaxation from electronic degrees of freedom. The pooling reaction between metastable $N_2(A^3\Sigma_u)$ states with 3.5 eV energy converted to translational energy [2] is found to be a dominate process responsible for the fast gas heating in pure nitrogen, as well as quenching of $N(^2D)$ atoms [3],

$$N(^2D) + N_2 \rightarrow N(^4S) + N_2(v)\,, \qquad (1)$$

which becomes extremely important at high gas temperatures. The temperature dependence of pooling reaction rate constant, which used in the model, was obtained based on the treatment of the experimental data [4].

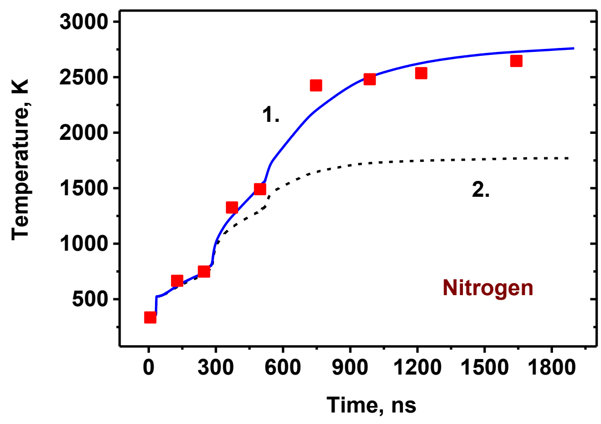

Fig. 1. Temporal evolution of gas temperature in nitrogen plasma at 27 mbar. Points – are experimental data, curves – are the results of calculations with (curve 1) and without (curve 2) the heat release in reaction (1).

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4. References

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