Measurements of Excited Metastable Species of Nitrogen in a Heated Nonequilibrium Plasma Flow Reactor

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Abstract: Time-resolved, absolute number densities of metastable atoms, $N(^2P)$ and $N(^2D)$, are measured in nitrogen in a heated plasma flow reactor, excited by a ns pulse discharge. The measurements are made by Atomic Resonance Absorption Spectroscopy, employing a "probe" ns pulse discharge generating resonance atomic emission lines in vacuum UV. The results are used to study the role of metastable atoms in associative ionization processes.

1. Introduction

A plasma flow reactor excited by a ns pulse discharge has been used previously for the generation of N atoms and long-lived metastable nitrogen molecules, $N_2(A^3\Sigma_u^+)$ [1,2]. These species serve as precursors for excited metastable atoms in the afterglow, produced during collisional quenching of $N_2(A^3\Sigma_u^+)$ by the ground state N atoms [3],

$$N_2(A^3\Sigma_u^+) + N \rightarrow N_2\left(X^1\Sigma_g^+\right) + N(^2P,\ ^2D) \tag{1}$$

which subsequently decay by associative ionization [4],

$$N(^2P) + N(^2P) \rightarrow N_2^+ + e^- \tag{2}$$

In the present work, Atomic Resonance Absorption Spectroscopy (ARAS) in vacuum UV is used for time-resolved measurements of metastable N atoms in the afterglow of a ns pulse discharge in in the flow reactor.

2. Methods

A nitrogen flow in a heated plasma flow reactor similar to the one used in our previous work [5], is excited by a repetitive ns pulse discharge operated at 100 kHz, generating a diffuse plasma with well-defined boundaries at T=300-1000 K. The measurements of metastable N atoms in the discharge afterglow are made using a second, "probe" ns pulse discharge to generate the atomic line emission, absorbed by the plasma in the main discharge. The transmitted probe discharge emission is collected through a MgF_2 window at the end of the flow channel, by an Acton VM-504 monochromator with a PMT detector. The measurements are made with the main discharge turned off and on, providing the baseline (I_0) and absorption (I) waveforms, respectively, for the absorption measurements.

3. Results and Discussion

The vacuum UV emission waveform near 174.25 nm, generated by the probe discharge at T=800 and P=50 Torr, is plotted in Fig. 1. The probe discharge bursts, 20 pulses long, are generated both before the main discharge burst, and at different time delays after the main discharge burst 40 pulses long, to detect the absorption by the metastable $N(^2P)$ atoms accumulated in the reactor, I/I_0. The absorption in the afterglow persists for at least 2 ms, when $I_0/I < 1$ (see Fig. 1). This indicates that $N(^2P)$ atoms accumulate during the main discharge burst, and decay in the afterglow. Similar behaviour is detected at 149.25 nm,

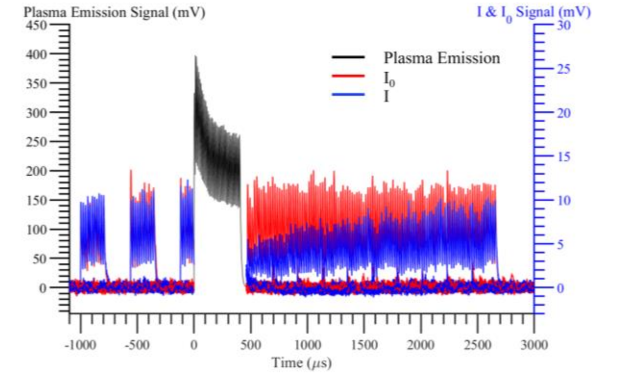

Fig. 1. Transmitted emission from the probe discharge at 174.25 nm, measured with (blue) and without (red) main discharge burst (black), at T=800 K, P=50 Torr. Absorption by $N(^2P)$ atoms is detected in the afterglow.

indicating absorption by $N(^2D)$ atoms. Their absolute number densities are inferred from the absorption data, using the synthetic spectra which incorporate the absorption line strengths and lineshapes.

4. Summary

The measurements of $N(^2D)$ and $N(^2P)$ atoms, in addition to our previous measurements of $N_2(A^3\Sigma)$ molecules and N_2^+ ions [6] will be compared with kinetic modeling, to infer the associative ionization rate coefficient in nitrogen plasmas, over a wide range of temperatures.

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