Kinetics of Neon Atmospheric Pressure Plasma Jets

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We propose a simple kinetic model to explain the discharge sustaining mechanism in atmospheric pressure plasma jets (APPJs) by taking into account the metastable kinetics. The discharge in neon APPJs is sustained by the balance between the creation and the loss of the total amount of ions and metastable atoms within the drift current using the simple kinetic model calculation.

1. Introduction

Atmospheric pressure plasma jets (APPJs) have recently attracted much interest not only for many applications [1] but also for plasma physics [2,3]. One of the most interesting phenomena in APPJs is bullet propagation [2]. Another is striation which has been observed between a nozzle exit and a conductive target plate in neon APPJs [3].

It is not clear, however, how the plasma is sustained in neon APPJs. Especially, the role and kinetics of the excited state (metastable) are not clear even though it is believed to be an important role [4]. In this paper, we studied the sustaining mechanism considering the metastable kinetics.

2.Sustaining mechanism and kinetics of discharge

In the experiment there are drift currents around 4 〜 8 mA at each peak between the nozzle exit and the conductive target plate for applied voltage and frequency of 2.9 k V and 61.7 kHz, respectively [3].

We assumed that the drift current consists of electrons that are supplied from ionization of both metastable and ground state atoms. The plasma is sustained by the balance between the creation of metastable atoms by the electron impact excitation from the ground state and the loss of the total amount of ions and metastable atoms.

A simple kinetic model is proposed to explain the sustaining mechanism. The kinetic model includes only neon and electron reactions, those are

1) $Ne + e \rightarrow Ne^* + e$,
2) $Ne + e \rightarrow Ne^+ + 2e$,
3) $Ne^* + e \rightarrow Ne^+ + 2e$,
4) $Ne_2^+ + e \rightarrow Ne^* + Ne$,
5) $Ne^* + Ne^* \rightarrow Ne^+ + Ne + e$,
6) $Ne^+ + 2Ne \rightarrow Ne_2^+ + Ne$,
7) $Ne^* + 2Ne \rightarrow Ne_2^* + Ne$,
8) $Ne_2^* \rightarrow 2Ne + h\nu$,

where e, Ne^+, Ne^*, Ne_2^+, and Ne_2^* are electron, neon ion, metastable atom, ion diatomic molecule, and excited diatomic molecule, respectively. The rate coefficients related to electrons depend on the electron energy distribution which was decided by the reduced electric field E/N, where N is the gas density. The rate coefficients and the drift velocity were calculated using the BOLSIG code [5]. In the model, Penning ionization by the mixing of neon gas with surrounding air were ignored.

3. Simulation results

We solved the rate equations for the reduced electric field, which was simplified based on the current waveform [3], assumed to be repetition of rectangular waves of E/N = 4.0 Td and their periods with 2.0 and 1.0 μs corresponding to positive and negative current, respectively. Figure shows the time evolution of the electron number density.

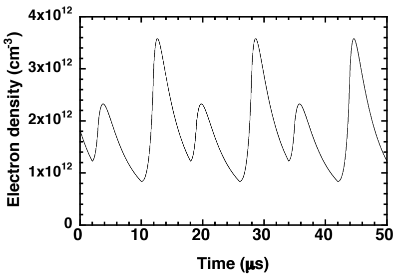

Fig. Time evolution of the electron number density.

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