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窒素・酸素プラズマ中の中性分子・分子イオンの回転温度差

Difference in Rotational Temperature between Neutral Molecules and Molecular Ions in N_2/O_2 Plasmas

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For a microwave discharge nitrogen plasma with its discharge pressure about 1 Torr, we found that the rotational temperature T_r of the first negative system (1NS) of N_2^+ B $^2\Sigma_u^+$ state is about 50 % times higher than that of the second positive system (2PS) of N_2 C $^3\Pi_u$ state, as shown in Fig. 1 by OES measurement. For 2PS, we found $0.07 \leq T_r$ [eV] ≤ 0.15, which is considered to be reasonable as an approximate value to the gas translational temperature [1]. On the other hand, the rotational temperature of 1NS is higher than that of 2PS, found to be about 0.13 – 0.34 eV. It is considered that this is partly because most of the excited molecular ions are generated by the electron impact from the ground state of ion, not of neutral molecule, where the electron temperature ranges from 2 to 4 eV and the electron density from 1×10^{11} to 1×10^{12} cm^{-3} [2]. Therefore, under the present discharge conditions, the rotational temperature could have a component that is originated from the ions N_2^+. It indicates that the rotational temperature of 1NS has some information on ion temperature if the rotational motion of ions is equilibrated with their translational motion.

Meanwhile, Fig. 2 shows that the rotational temperature of 1NS of O_2^+ b $^4\Sigma_g^-$ state is almost the same as that of atmospheric absorption band (A-band) of O_2 b $^1\Sigma_g^+$ state [3]. The electron temperature and density are almost the same with those of the nitrogen plasma. Consequently, we consider that O_2^+ b $^4\Sigma_g^-$ state is mostly produced from the electron impact from the ground state (X state) of O_2^+ ion. However, the

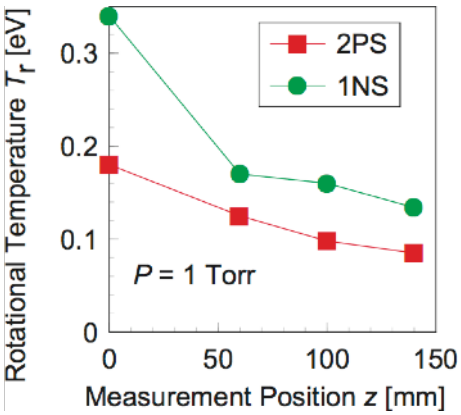

Fig. 1. Rotational temperature of 2PS band of N_2 and that of 1NS band of N_2^+ of N_2 plasma depicted in Ref. [1].

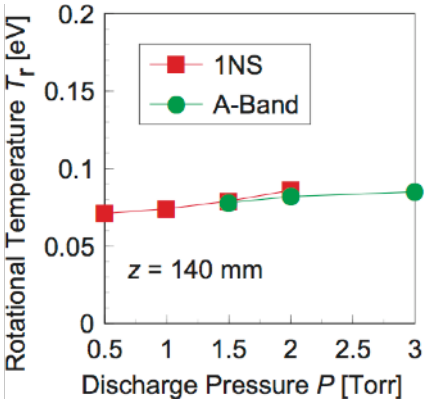

Fig. 2. Rotational temperature of A-band of O_2 and that of 1NS of O_2^+ of O_2 plasma in Ref. [3].

rotational temperature is almost the same with that of neutral O_2 b $^1\Sigma_g^+$ state, which is quite different from N_2 plasma. Now we consider that the rotational temperature of the ground state of O_2^+ ion, that is, O_2^+ X $^2\Sigma_g^+$ state should be much higher than that of the O_2^+ b $^4\Sigma_g^-$ state due to the difference in the intermolecular distance R, where that of the b state R_b =1.2797 Å is much larger than that of the ground state, R_X = 1.1171 Å. The angular momentum of both X and b states are almost conserved before and after the electron impact excitation due to a small mass of an electron. Therefore, the rotational temperature of the X state $T_r(X)$ of O_2^+ ion should be estimated as $T_r(X) \sim T_r(b) \times (R_b/R_X)^2 = 1.32 \times T_r(b)$. This value, in some sense, gives a similar result with that of nitrogen plasma, where the intermolecular distance of both B and X states of N_2^+ ion is almost the same. Consequently, it is considered that the ground-state molecular ion has higher rotational temperature than neutral molecule, both for nitrogen and oxygen discharge plasmas under the present discharge conditions. We should further study the reason why molecular ions have higher rotational temperature than neutral molecules.

[1] T. Sakamoto, H. Matsuura and H. Akatsuka: J. Appl. Phys., **101**, 023307 (2007).
[2] H. Kawano, A. Nezu, H. Matsuura and H. Akatsuka: Abst. 8th EU-Jpn. Joint Symp. Plasma Proc. (JSPP2012) P07 (2012).
[3] H. Akatsuka, K. Naoi and H. Matsuura: Papers Tech. Meeting Plasma Sci. Technol & Pulsed Power Technol., IEE Jpn., PST-11-95, PPT-11-96, pp. 21 – 26 (2011).