Difference in Rotational Temperatures between Neutral Molecules and Molecular Ions of N_2-O_2 Plasmas of Low-Pressure Microwave Discharge

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For a microwave discharge nitrogen plasma with its discharge pressure about 1 Torr, it is found that the rotational temperature T_r of the first negative system (1NS) of N_2^+ B $^2\Sigma_u^+$ state is about 1.5 times higher than that of the second positive system (2PS) of N_2 C $^3\Pi_u$ state 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]. 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 10^{11} to 10^{12} cm^{-3}. Therefore, under the present discharge conditions, the rotational temperature could have a component originated from N_2^+, and could have some information on the ion temperature.

Meanwhile, it is found that the rotational temperature of 1NS of O_2^+ b $^4\Sigma_g^-$ is almost the same as that of atmospheric absorption band of O_2 b $^1\Sigma_g^+$ state, which is quite different from N_2 plasma. The electron temperature and density are almost the same with those of the nitrogen plasma. We consider that the rotational temperature of the ground state O_2^+ X $^2\Sigma_g^+$ should be much higher than that of O_2^+ b $^4\Sigma_g^-$ state due to difference in the internuclear 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 $T_r(X) \simeq T_r(b) \times (R_b/R_X)^2 = 1.32 \times T_r(b)$. This value gives a similar result with that of nitrogen plasma, where the internuclear distances of B and X states of N_2^+ are almost the same. It is considered that the ground-state molecular ion has higher rotational temperature than neutral molecule, both for nitrogen and oxygen 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).