Metastables as a Probe for Low-Temperature Plasmas
Correlation between N* and n_e in Ar

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Large number of experimental and theoretical studies of neutral metastables in argon have been performed in order to explore and clarify the macroscopic and the microscopic characteristics of low-temperature plasma sources for over three decades. The accumulated set of data comprising number density and temperature of the metastable, N^* and T_g, as well as the electron density n_e in various kinds of low-temperature plasmas over a wide range of external parameters enable the analysis and review of the inner plasma parameter in the form of the relative densities, N^*/N_g and n_e/N_g normalized by the feed gas density N_g, based on a simple theoretical rate equation in real space,

$$\frac{\partial}{\partial t}N^*(t) = k_m n_e N_g - k_{Teq} n_e N^* - k_{mp} N^* N^* - k_{3sq} N^* N_g^2 - k_{imp} N_{imp} N^* - \frac{D_m}{\Lambda^2} N^*$$

Indispensable is the development of the non-invasive diagnostics for metastables, and of the tunable diode laser in a visible-near infrared domain ($\lambda < 1\mu m$). It enabled optical absorption spectroscopy for measurements of N^* and T_g of the metastable in Ar. A reasonable cross-correlation in the above equation,

$$\frac{n_e}{N_g} = -\frac{k_{mp}}{k_{Teq}}\frac{N^*}{N_g} - \frac{k_{mp}}{k_{Teq}}\left(\frac{k_m}{k_{Teq}} + \frac{I_d}{k_{mp}}\right)\left(1 + \frac{k_m}{k_{Teq}}\frac{1}{\left(\frac{N^*}{N_g} - \frac{k_m}{k_{Teq}}\right)}\right)$$

is found between N^*/N_g and n_e/N_g during a steady-state under condition without three-body collision and diffusion, i.e., $I_d = 0$. A strong positive correlation between N^*/N_g and n_e/N_g in the present analysis demonstrates that the metastable density N^* can be an indirect indicator of the plasma density n_e in a low-temperature plasma. It will be noted, in addition, that the high-sensitivity of electrons to the surrounding local field makes it difficult to observe the local density and its distribution in a low-temperature plasma even though there exist several traditional methods to measure n_e. The details of the present result are published as the review article [1].

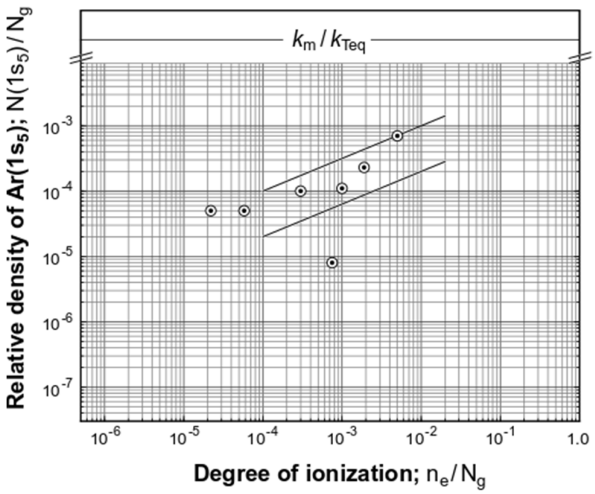

Figure: Example in micro hollow-cathode discharge under various external parameters.

References

[1] T. Makabe, *J. Phys. D*, **52**, (2019), 213002 and **52**, (2019), 259601.