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Measurement of Recombination Coefficient on Low Catalyst Material Using Microwave Discharged Plasma

マイクロ波放電プラズマを用いた低触媒材料における再結合係数の計測

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This paper introduced a system to measure the surface catalysis on a thermal protection system (TPS). This system simulated an environment behind the shock wave in front of the re-entry vehicle using microwave discharged plasma. And these flow properties (atomic number density, translational temperature etc.) are measured by using two-photon absorption laser induced fluorescence. Finally, the recombination coefficients on SiC (usually TPS material) are estimated experimentally.

1. Background

When a re-entry vehicle enters the atmosphere of a planet, a strong bow shock is formed in front of the vehicle's body [1]. Therefore appropriate designing of a thermal protection system (TPS) for a re-entry vehicle is one of the most important issues for space missions. In such a high temperature environment, air is dissociated in the shock layer, and following recombination reactions on the TPS materials are promoted due to the surface catalysis for the case of Earth entry.

$$
\begin{aligned}
O+O &\rightarrow O_2 + 5.13[\mathrm{eV}] \\
N+N &\rightarrow N_2 + 9.80[\mathrm{eV}] \\
N+O &\rightarrow NO + 6.53[\mathrm{eV}]
\end{aligned}
\qquad (1)
$$

The schematic of this phenomenon is illustrated in Fig. 1. This characteristic is so-called the surface catalysis. The surface catalysis significantly affects the aerodynamic heating rate. It is necessary to take into account the surface catalysis on the TPS material in order to design a reliable TPS. Then, the surface catalysis is estimated by the recombination coefficient.

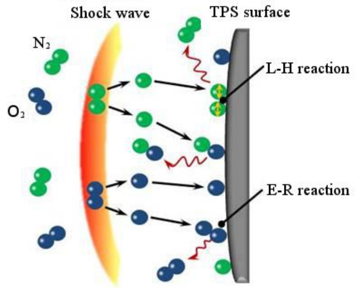

Fig. 1. Schematic of recombination model due to the surface catalysis on TPS surface.

2. Experimental Setup and Analysis

In this paper, the recombination coefficient was derived from measurements of the fluorescence signals induced by two-photon excitation of atomic oxygen. Figure.2. shows experimental setup of TALIF.

TALIF signal is proportional to number density of atomics. Equation (2) was derived from Ref[2].

$$
S \fallingdotseq \frac{\Delta\Omega}{4\pi}\eta_\lambda V \frac{A}{A+Q}\hat{\sigma}^{(2)} N_1 G^{(2)} \cdot g(2\nu_L - \nu_0)\left(\frac{E_L}{A_L h\nu_L}\right)^2 \int_0^\infty I_0{}^2(t)dt \qquad (2)
$$

Figure 2 shows spectral data of two-photon absorption fluorescence from atomic oxygen. In this study, fluorescence data averaged by 50 pulses. After that, the fluorescence intensity and decay rate are estimated by fitting an exponential function. From this fluorescence, flow properties (atomic number density, translational temperature, quenching rate etc.) can be estimated[3]. In Eq. (2), the ground-state number density depletion is ignored. However, these factors affect the TALIF signal with high laser intensity. Therefore, saturation effect was checked in chamber under 20Pa pressure. The result is shown in Fig.5. Under 500μJ, fluorescence signal is proportional to square of laser intensity. So the signals are not saturated and this region is used to measure the some results.

Equation (3) shows the recombination coefficient [4].

$$\gamma_O = \frac{4D_O}{V^*L}\left(\frac{(N_O)_{z=L}}{(N_O)_{z=0}} - 1\right) \qquad (3)$$

These parameters (D_O: Diffusion coefficient, V^*: Thermal velocity) are function of temperature and pressure of flow.

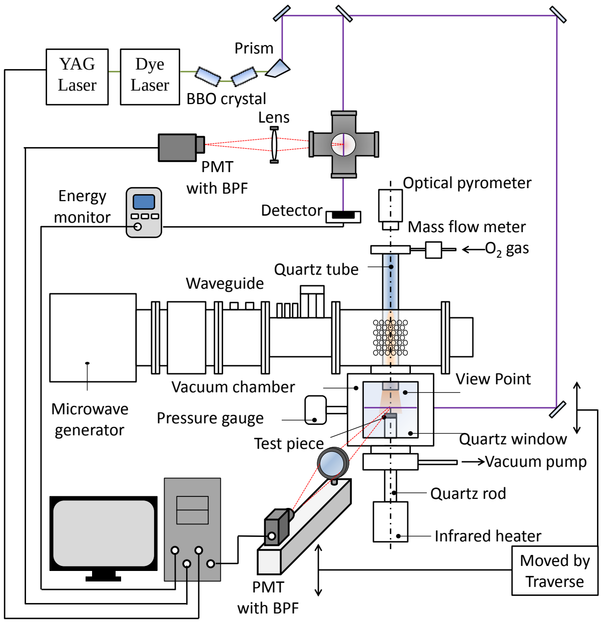

Fig. 2. Experimental setup of TALIF

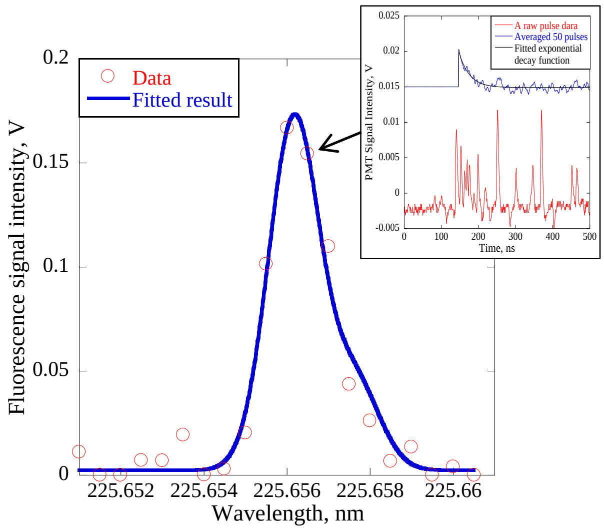

Fig. 3. Spectral data of two-photon absorption fluorescence from atomic oxygen & raw-analyzed pulse data

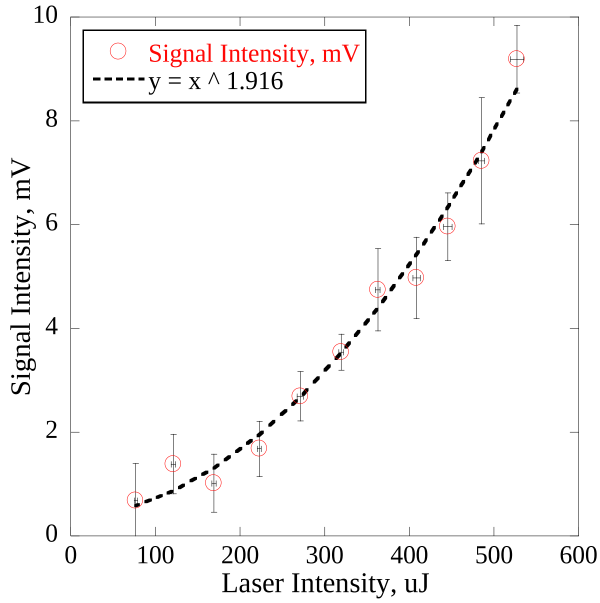

Fig. 5. Fluorescence signal data

3. Summary

In this paper, an experimental setup and analysis method was introduced. From these methods, we will measure the atomic number density and translational temperature on TPS material. After that, the recombination coefficients are estimated using these parameters. The results will be reported at conference.

References

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