23P009-O

Electron behaviors in methane and air pre-mixture gas flame under microwave electric field
マイクロ波照射による空気メタン予混合ガス火炎中の電子の挙動

Haruaki Akashi[1], Tomokazu Yoshinaga[1], Koichi Sasaki[2]
明石　治朗[1], 吉永　智一[1], 佐々木　浩一[2]

[1]*Dept. Appl. Phys., National Defense Academy, 1-10-20 Hashirimizu Yokosuka, 239-8686, Japan*
防衛大学校 応用物理学科　〒239-8686 横須賀市走水1-10-20
[22]*Div. Quant. Sci. and Eng., Hokkaido University, N13-W8 Kita Warad, Sapporo, 060-8628 , Japan*
北海道大学大学院　量子理工学部門　〒060-8628 札幌市北区北13条西8丁目

Recently, plasma-assisted combustion has been focused on for achieving more efficient combustion way of fossil fuels and so on. Shinohara et al has reported that the flame length of methane and air premixed burner shortened by irradiating microwave power without increase of gas temperature. This suggests that electrons heated by microwave electric field assist the combustion. To clarify this mechanism, electron Monte Carlo simulations and simple rate equations in methane and air mixture gas have been done. And it is found that the simulated emission from Second Positive Band System agrees with the experimental result.

1. Introduction

Recently, plasma-assisted combustion[1] has been focused on due to achieve more efficient way of fossil fuels combustion, reducing pollutants and so on. Shinohara et al[2] has reported that the flame length of methane and air premixed burner shortened by irradiating microwave power without increase of gas temperature. This result suggests the electron heating by microwave power affect on burning velocity in combustion system. To clarify this phenomena, electron behavior under microwave power should be examined. For the first step, in this paper, electron Monte Carlo simulation in methane and air mixture gas has been done.

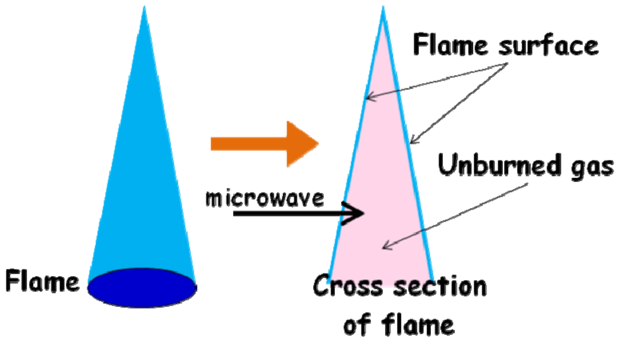

Figure 1. Configuration of present model.

2. Modeling

To simulate inside the flame under microwave electric field, zero dimensional model was used. The simulated area is inside the flame as shown in Figure 1(unburned gas area).

To determine the electron energy distribution function (eedf) and transport parameters, electron Monte Carlo simulation has been done in zero dimension. The simulated conditions are applied electric field ~300V/cm with frequency of 2.45GHz and the total gas pressure of 1atm. The gas temperature is assumed to be 2000K. The gas is mixture of nitrogen, oxygen and methane and the mixture ratio is 8:2:1. Figure 2 shows the eedfs obtained from e-MCS. As shown in the Figure, as the electric field decreases, high energy electrons decrease significantly. It is found that the electric field at more

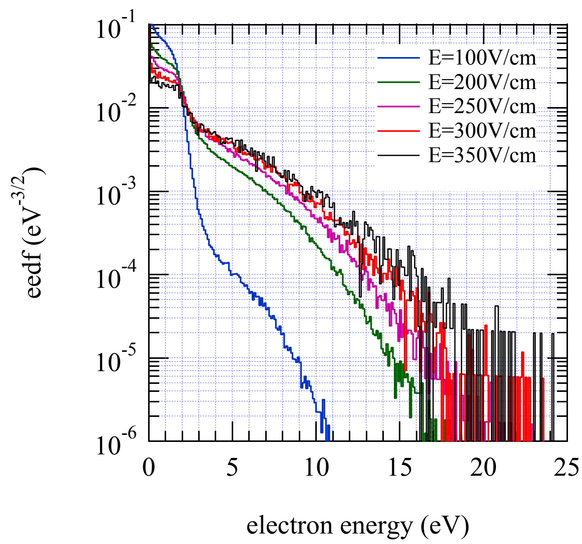

Figure 2. Electron energy distribution functions in methane and air.

than 300V/cm is suitable for this model. To solve inside the flame using simple rate equations, the parameters and reactions written below were used.

Electric field: 300V/cm, Freq.2.45GHz
Excitation frequency for C^3P_u: $1.1\text{x}10^7$(1/s)
Electron density 1.0(cm^{-3})
Einstein's A coefficient: $2.45\text{x}10^7$(1/s)

Reactions considered

$N_2 + e \rightarrow N_2^*(C) + e$
$N_2^*(C) \rightarrow N_2^*(B) + h\nu$
$N_2 + e \rightarrow N_2^*(A) + e$
$N_2^*(A) + N_2^*(A) \rightarrow N_2^*(C) + N_2$
$N_2^*(C) + N_2 \rightarrow N_2^*(a') + N_2$
$N_2^*(C) + O_2 \rightarrow N_2 + O + O$
$O_2^- + N_2^*(A) \rightarrow O_2 + N_2 + e$
$O_2^- + N_2^*(B) \rightarrow O_2 + N_2 + e$

At this condition, effective ionization freq. is almost zero. And gas flow is assumed and the value is 5 l/min.

The electron density was solved using eq. (1)

$$\frac{dn_e}{dt} = C - \frac{n_e}{\tau} \quad (1)$$

C is assumed to be electron density which is diffused from the flame and τ is assumed as electron loss coefficient by gas flow.

3. Results and discussions

Figures 3 and 4 show temporal evolution of electron density and Intensity from 2nd positive band system in nitrogen gas. In Figure 3, electron density quickly increases as microwave electric field is applied. And the electron density reaches about $2\text{x}10^6 cm^{-3}$. After the electric field is off, the electron density gradually decreases. As shown in Figure4, The intensity from 2nd positive band system in nitrogen gas agrees with the experimental results. It is found that the time constant τ_{ON} is related to gas flow parameter. It is not shown in the paper, but the intensity is not so sensitive by the time constant τ_{ON}. And the initial electron density sensitivity is also examined. And it is found that the value of the initial electron density supposes to be low.

Acknowledgments

This work was supported by Grant-in-Aid for Scientific Research (B) 22340170

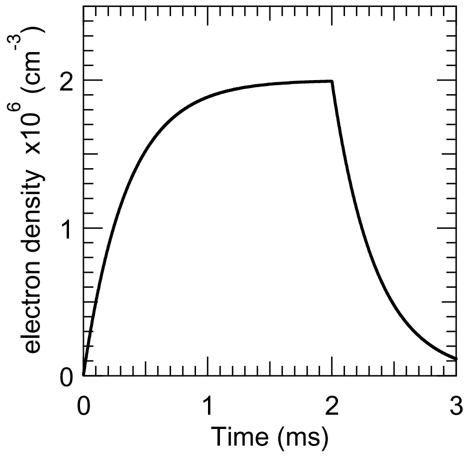

Figure 3. Temporal evolution of Electron density .

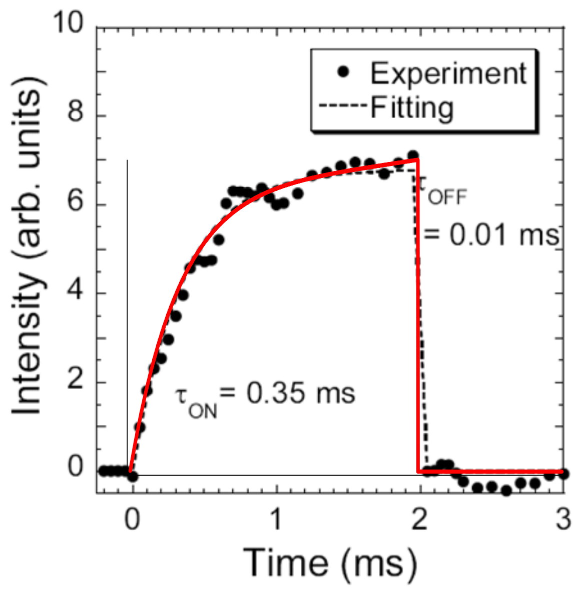

Figure 4. Intensity from 2nd positive band system .

References

[1]V.Bychkov et al. IEEE Trans. Plasma Sci.,37,12 2280-2285 (2009)

[2] K. Shinohara et al, J. Phys. D:Appl. Phys., 42, 182008 (1-7) (2009)