Topic number 17

Structure at the top of premixed burner flame with the superposition of pulsed dielectric barrier discharge

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We investigated the transient phenomena in a premixed burner flame with the superposition of a pulsed dielectric barrier discharge (DBD). The length of the flame was shortened by the superposition of DBD, indicating the activation of combustion chemical reactions with the help of the plasma. We observed the modulation of the top position of the flame and the formations of local minimums in the axial distribution of the optical emission intensity of OH. These experimental results reveal the oscillation of the rates of combustion chemical reactions as a response to the activation by pulsed DBD. The cycle of the oscillation was 0.18-0.2 ms, which could be understood as the eigenfrequency of the plasma-assisted combustion reaction system.

1. Introduction

We have shown that the burning velocity is enhanced by superposing a dielectric barrier discharge (DBD) onto the bottom part of a steady-state premixed burner flame. The increase in the burning velocity is understood by the shortening of the flame length. However, it has been also observed that the flame length was not stationary. In this work, we report the transient change in the shape of premixed burner flame with the superposition of pulsed DBD.

2. Experiment

A premixed burner was fixed on a dielectric base plate. The side of the flame was covered with a quartz tube. A 10-mm-high aluminium electrode was attached on the outside of the quartz tube, and it was connected to a high-voltage power supply with an oscillation frequency of 1 kHz. The burner was electrically grounded. Asymmetric DBD was produced inside the quartz tube and was superposed onto the bottom part of the flame using this experimental configuration. The image of the optical emission intensity of OH from the top part of the flame were captured using an ICCD camera. In addition, laser-induced fluorescence (LIF) imaging spectroscopy was employed to estimate the spatial distribution of the ground-state OH radical density.

3. Results and discussion

Figure 1(a) shows the optical emission image of the top part of the flame in the absence of DBD, while we observed the optical emission images shown in Figs. 1(b)-1(k) in the presence of DBD at various phases of the applied voltage. We observed the temporal variation in the flame length in the presence of DBD. In addition, we observed the formation of local minimums in the axial distribution of the optical emission intensity. As illustrated by the oblique broken lines in the figure, the local minimums moved toward the upper side of the vertical direction at a constant speed. The propagation speed of the local minimums agreed well with the flow speed of the gas. The interval between the arrival times of the local minimums at the fixed position was approximately 0.18-0.2 ms, suggesting that the rates of combustion reactions become less efficient at the interval of 0.18-0.2 ms in the bottom part of the flame. The less efficient reactions may be caused by the overshooting of the rates of combustion reactions by the superposition of the pulsed plasma. Therefore, the interval of 0.18-0.2 ms could be understood as the eigenfrequency of the plasma-assisted combustion reaction system.

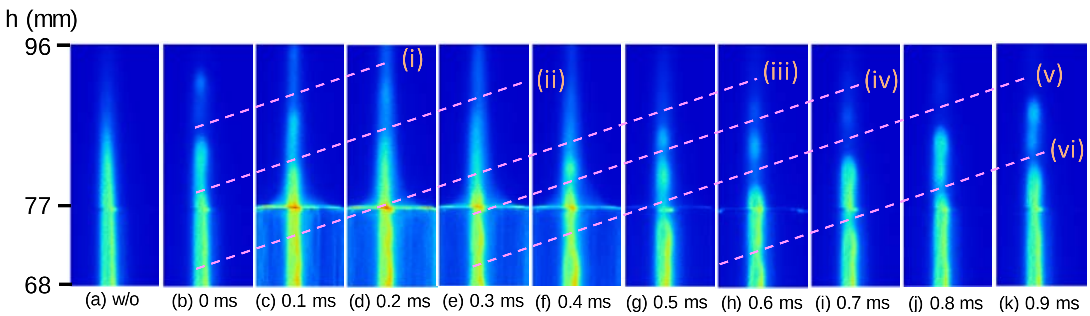

Fig. 1 Optical emission images of the top part of the flame observed in the absence (a) and presence (b)-(k) of DBD