Effects of hydrogen addition on the preheating zone and soot generation of ethylene/air/nitrogen inversed diffusion flames

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Abstract

In recent years, governments around the world have been increasingly concerned about the environmental impact of soot. The blending of hydrogen and hydrocarbons has been gaining popularity due to its zero-carbon characteristic. Therefore, this study investigates the effect of hydrogen substitution for partial hydrocarbon fuels on soot formation and preheating zone in a triple-port inverse diffusion flame. The detailed experimental setup of gas feeding is shown in Figure 1. The fuel stream consists of a mixture of ethylene and hydrogen, and the oxidizer stream consists of 33% Oxygen and 67% Nitrogen. The ratio of oxidizer velocity to fuel velocity (define as R ratio) is fixed at R = 7.6 to ensure the formation of a standard inverse diffusion flame, as shown in Figure 4. This study utilized non-intrusive laser diagnostic systems to detect intensity signals of soot and formaldehyde. For this purpose, the 532 nm excited wavelength and a 600 nm detected wavelength are selected for LII, and the 355 nm exited wavelength and a detection range of 383-550 nm are employed for CH_2O-PLIF. The detailed experimental setups for the LII and CH_2O-PLIF laser systems are shown in Figures 2 and Figure 3, respectively. Additionally, the flame height was defined using the chemiluminescence of CH^*. Figure 5 and Figure 6 show the composite figures of CH^* with CH_2O-PLIF and true flame and CH^* with LII and true flame, respectively. The results of Figure 5 indicate that the intensity of formaldehyde fluorescence gradually decreases while hydrogen increasing. The center tip moves downstream because (1) the additional hydrogen reacts with the oxidant to generate more OH and consume CH_2O to be HCO radicals, and (2) the decreasing hydrocarbon reduces CH_2O radical formation. The soot zone is visibly reduced in both the LII signal and real flame, as shown in Figure 6. The normalized signal flux demonstrates an inverse proportion to the amount of hydrogen added, indicating two possible explanations for these trends. (1) Hydrogen may react with oxygen to promote the generation of H_2O, which in turn reduces the soot. (2) the addition of hydrogen may lead to a reduction in soot precursors, such as PAH and C_3H_3. Figure 7, which shows the overlapping LII and CH_2O-PLIF images, indicates that the formaldehyde profile is highly correlated with LII and therefore can be considered a reliable indicator. These results are crucial for developing cleaner and more efficient combustion technologies to reduce environmental impacts.

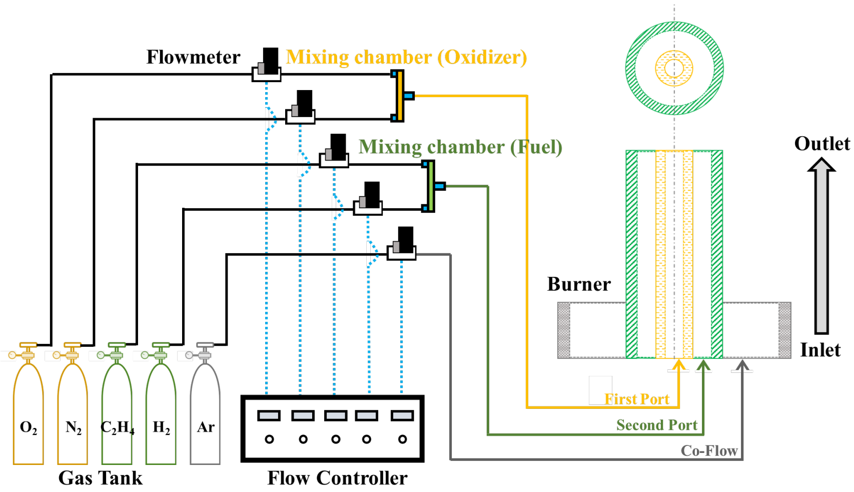

Figure 1: Experiment setup of gas feeding and burner.

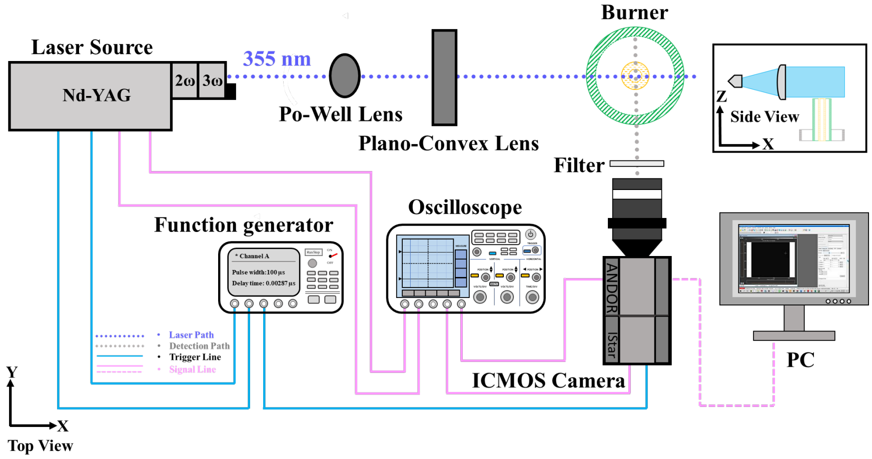

Figure 2: Experiment setup of CH_2O-PLIF.

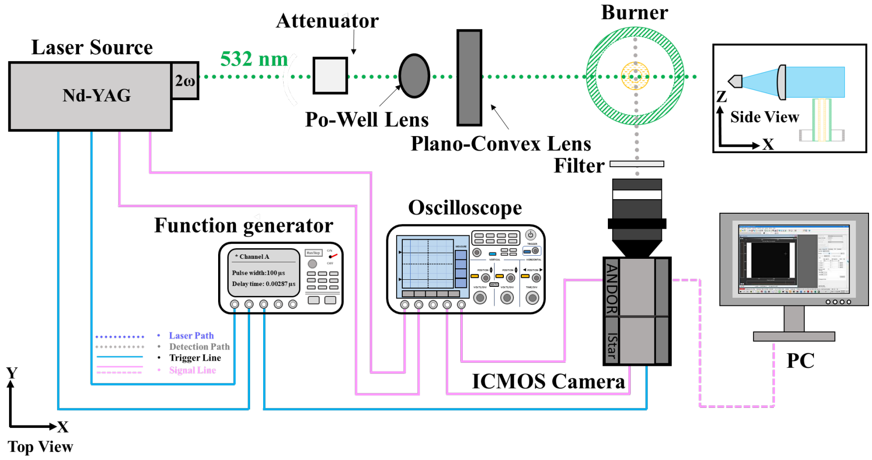

Figure 3: Experiment setup of LII.

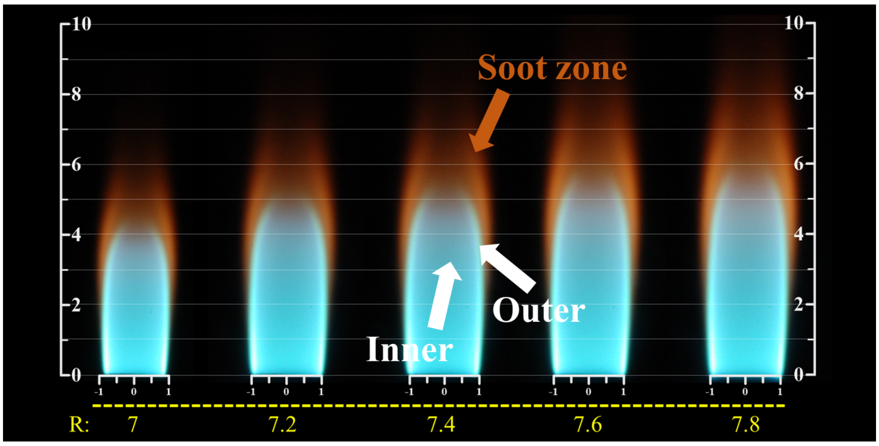

Figure 4: Various R ratios of flames appearance from 7 to 7.8 by the interval of 0.2

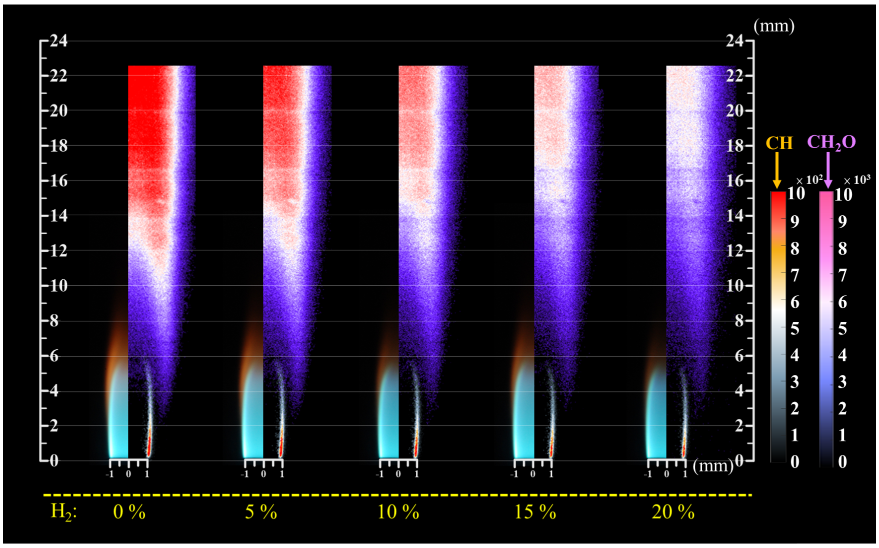

Figure 5: CH_2O-PLIF and CH^* chemiluminescence signals with real flames of various hydrogen additional concentrations by the interval of 5%

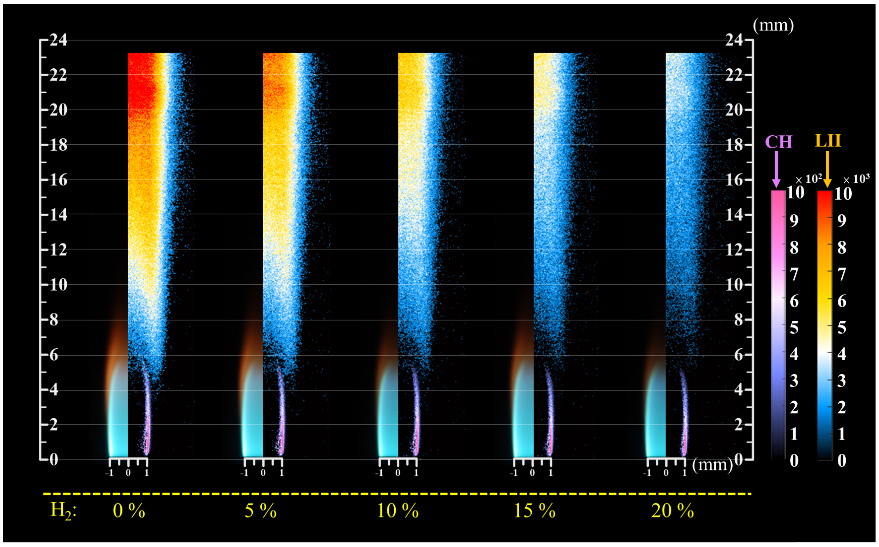

Figure 6: LII and CH* chemiluminescence signals with real flames of various hydrogen additional concentrations by the interval of 5%

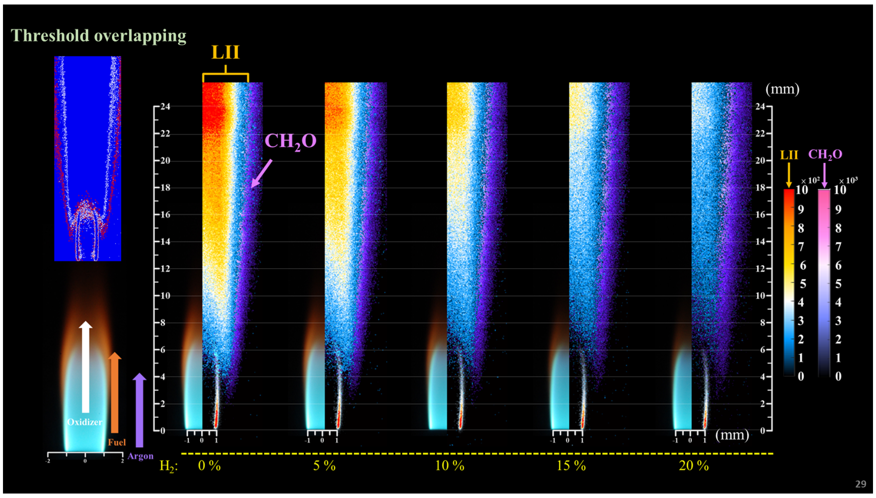

Figure 7: Overlapping distribution of the LII and CH_2O-PLIF signals with real flames of various hydrogen additional concentrations by the interval of 5%