Electronic Supplementary Material

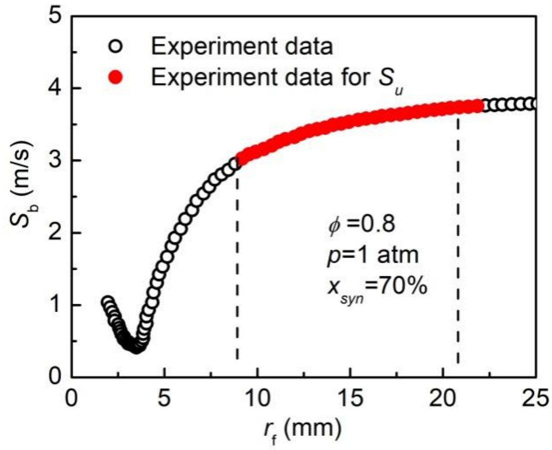


Fig. S1 Change of stretched flame propagation speed with flame radius.

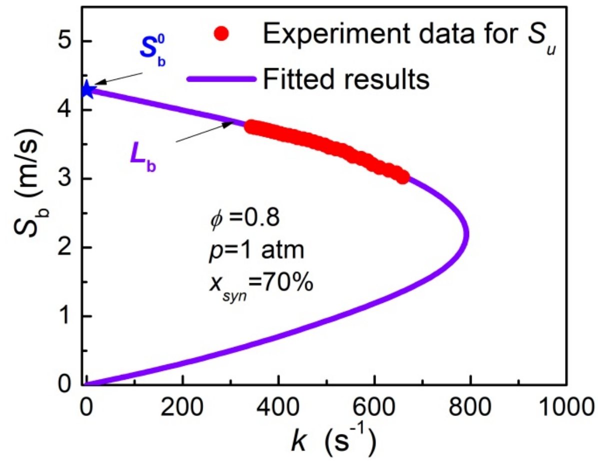
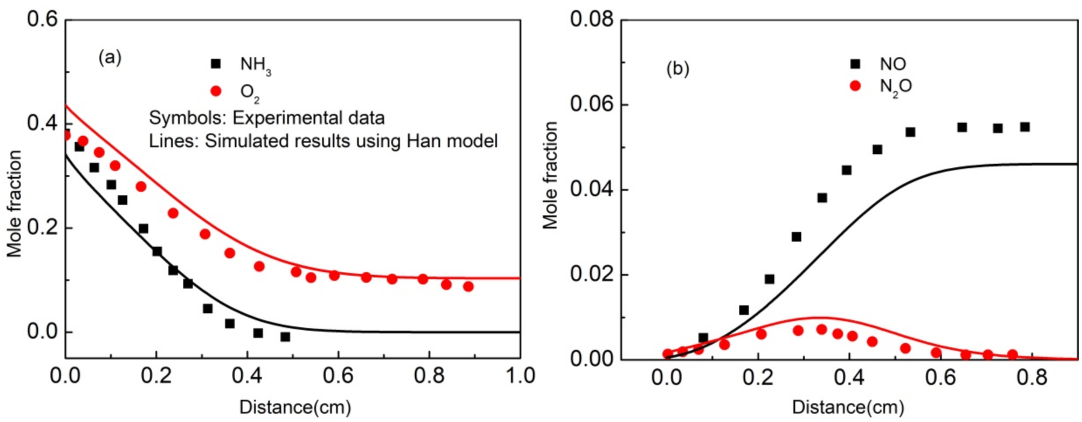


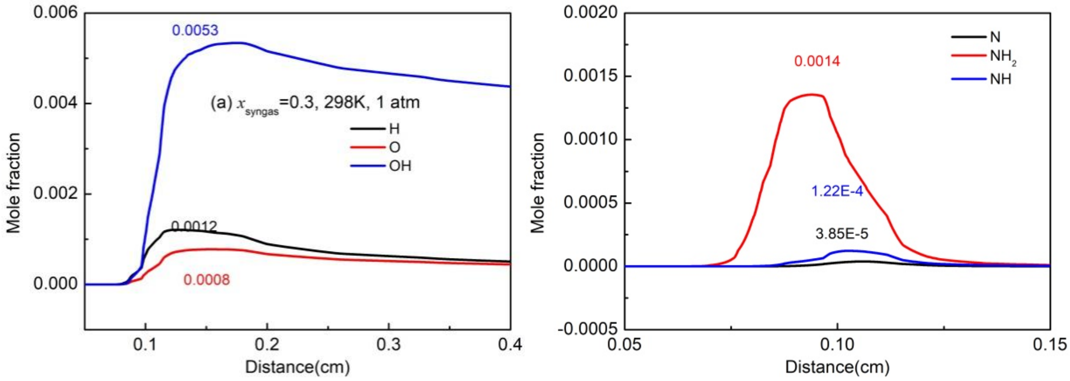
Fig. S2 Nonlinear methods on extraction of unstretched flame speed.



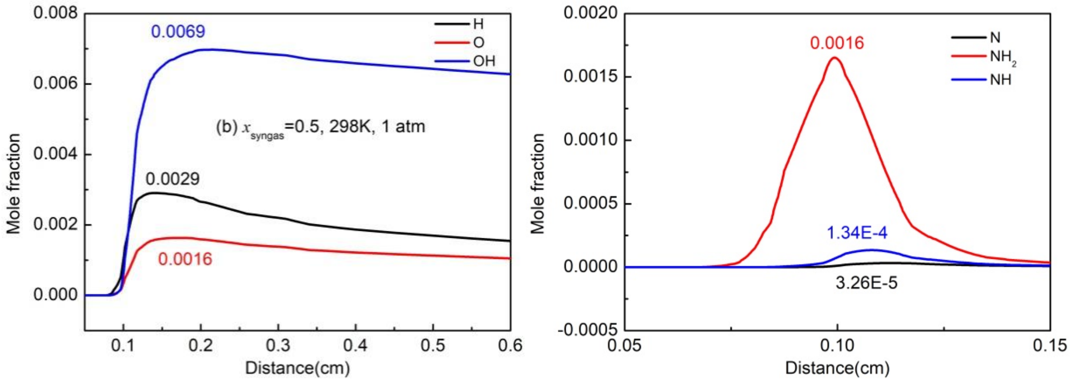
(a) (b)

Fig. S3 Comparison of measured mole fractions in a low-pressure premixed ammonia/oxygen flame (at a pressure of 4666.28 Pa; inlet composition of 48% NH_3, 51% of O_2, and 1% of Ar, a gas velocity of 60.8 cm/s, and a peak flame temperature of about 2250 K).

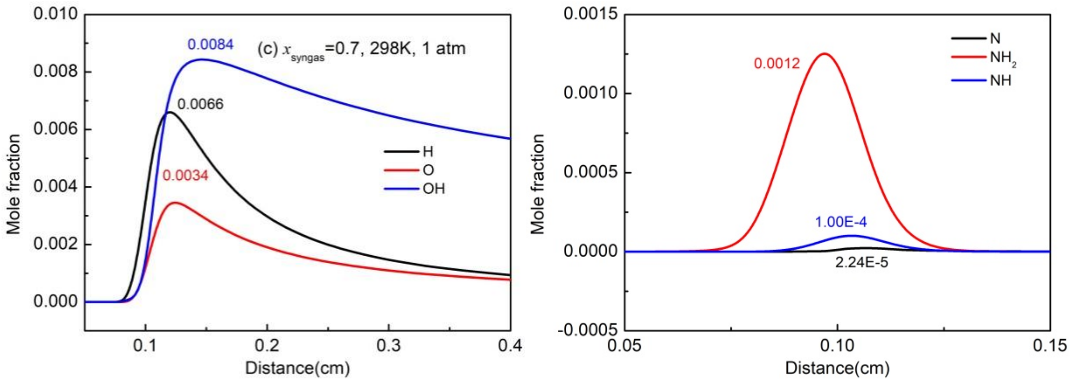
(a) Mole fractions of NH_3 and O_2; (b) mole fractions of NO and N_2O.



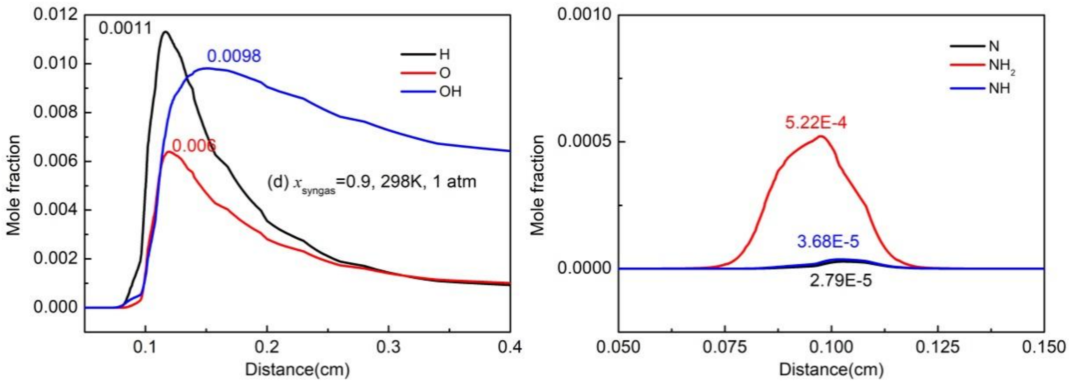
(a)



(b)



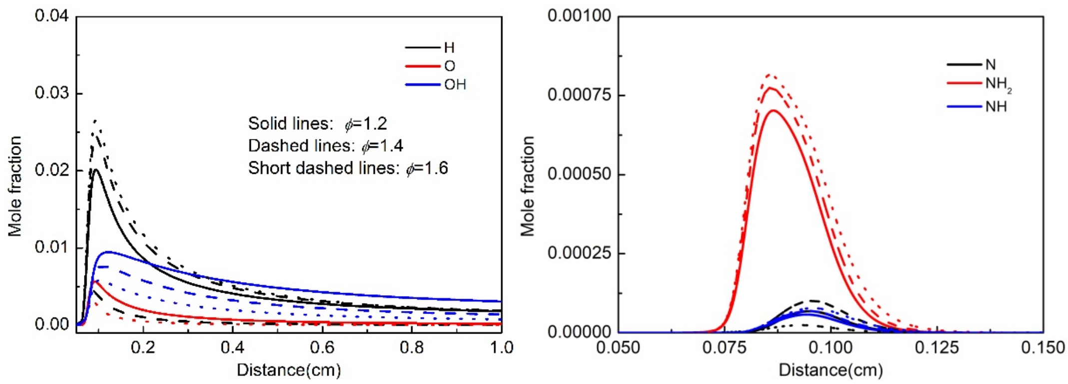
(c)



(d)

Fig. S4 Radical analysis at different syngas ratio from 0.1 to 0.9.

(a) x_{syn} =0.3, p = 1 atm, and T = 298 K; (b) x_{syn} =0.5, p = 1 atm, and T = 298 K; (c) x_{syn} =0.7, p = 1 atm, and T = 298 K; (d) x_{syn} =0.7, p = 1 atm, and T = 298 K.



(a) (b)

Fig. S5 Radical analysis at different equivalence ratios of 1.2, 1.4, and 1.6.

(a) Mole fractions of H, O, and OH; (b) mole fractions of N, NH_2, and NH.

Uncertainty analysis of the laminar flame speed

The uncertainty of laminar flame speeds is mainly estimated from radiation, temperature, pressure, and mixture preparation. Radiation can affect the flame speed through radiation heat loss and radiation reabsorption. The heat loss can reduce the flame propagation speed while the radiation reabsorption can accelerate the flame propagation speed. The effect of radiation can be estimated using the equation proposed by Yu et al. [1], expressed as

$$S_{\mathrm{u,RCFS}}^{0}=S_{\mathrm{u,EXP}}^{0}+0.82S_{\mathrm{u,EXP}}^{0}\left(S_{\mathrm{u,EXP}}^{0}/S_{0}\right)^{-1.14}(T_{\mathrm{u}}/T_{0})(P_{\mathrm{u}}/P_{0})^{-0.3}, \qquad (8)$$

where T_0 = 298 K, S_0 = 0.01 m/s, P_0 = 0.1 MPa; $S_{\mathrm{u,RCFS}}^{0}$ and $S_{\mathrm{u,EXP}}^{0}$ are the radiation-corrected and measured laminar flame speed, respectively.

The uncertainty deduced from other factors are examined as the total uncertainty by the theory presented in Moffat [2] which is given by

$$\delta_{S_{\mathrm{u}}^{0}}=\sqrt{\left(B_{S_{\mathrm{L}}}\right)^{2}+\left(\frac{t_{M-1.95}S_{S_{\mathrm{L}}}}{\sqrt{M}}\right)^{2}}, \qquad (9)$$

where M is the repeating times for each experimental condition, $t_{M-1.95}$ stands for the distribution of student t at a confidence interval of 95% and the freedom degrees of M–1; $S_{S_{\mathrm{L}}}$ indicates the standard deviation of S_{u} obtained from repeated experimental results under each condition; $B_{S_{\mathrm{L}}}$ is the total bias uncertainty of the determination methodology and can be estimated by

$$B_{S_{\mathrm{L}}}=\sqrt{\sum_{i=1}^{n}\left(\frac{\partial S_{\mathrm{L}}(x_{i})}{\partial x_{i}}u_{i}\right)^{2}}, \qquad (10)$$

where x_i indicates each factor which affects the accuracy of the laminar flame speed and u_i is the deviation of the factor. Actually, the laminar flame speeds can be expressed using these factors like temperature, pressure, and equivalence ratio as

$$S_{\mathrm{u}}=S_{\mathrm{u}}^{0}(\varphi)(T_{\mathrm{u}}/T_{\mathrm{u0}})^{\alpha(\varphi)}(P_{\mathrm{u}}/P_{\mathrm{u0}})^{\beta(\varphi)}(x_{\mathrm{u}}/x_{\mathrm{u0}})^{\gamma(\varphi)}, \qquad (11)$$

where the referenced initial temperature T_{u0} was 298 K, referenced initial pressure P_{u0} was 0.1 MPa, and x_{u0} was 0.5. The uncertainty of temperature derives from the uncertainty of thermocouple was estimated to be 3 K. The initial temperature is 298 K, 373 K, and 453 K, respectively. Therefore, the biggest relative error of temperature was less than ±1%. Because the deviation between the target and the actual pressure was ±1 kPa, the relative error of pressure was within ±1%. The fuels were introduced into the chamber by microliter syringes, whose amount was presented by practical pressure controlled by a high precision pressure transmitter and a micro adjustable valve. The uncertainty of the equivalence ratio mainly derived from the uncertainties in measuring the partial pressures of fuel, O_2, and N_2. In addition, fuel mixtures were prepared before each experiment. Thus, the uncertainty of the syngas ratio was calculated according to the practical partial pressures of each component. The 0.075%

uncertainty resulting from the precision of pressure transmitter would lead to a 1%–3% uncertainty in equivalence ratios and syngas ratios. In conclusion, the total uncertainty of laminar flame speeds estimated using the method above is about 0.2 to 2.0 cm/s.

References

[1] Yu H, Han W, Santner J, et al. Radiation-induced uncertainty in laminar flame speed measured from propagating spherical flames. Combustion & Flame, 2014,161(11): 2815–2824

[2] Mofat R J. Describing the uncertainties in experimental results. Experimental Thermal and Fluid Science, 1988, 1(1): 3–17