Electronic supplementary materials

For https://doi.org/10.1631/jzus.A2200468

Effect of carbon dioxide concentration on the combustion characteristics of boron agglomerates in oxygen-containing atmospheres

Lian DUAN, Zhixun XIA, Yunchao FENG, Binbin CHEN✉, Jiarui ZHANG, Likun MA

College of Aerospace Science and Engineering, National University of Defense Technology, Changsha 410073, China

✉ Binbin CHEN, chenbinbin11@nudt.edu.cn

Section S1 Temperature calculation method and error analysis:

Before each spectral signal measurement by the spectrometer, the spectral intensity was calibrated using an Ocean Optics LS-1-CAL halogen tungsten calibrator. An optical collimator with a diameter of 5 mm was installed at the end of the optical fiber. The optical collimator was placed 130 mm from the particle and aimed at the center of the particle. Due to the strong dependence of spectral intensity on temperature, it is generally considered that the measured temperature is automatically biased towards the temperature of the brightest emitter along the optical path (Weismiller et al., 2011). The boiling point of boron is as high as 3931 K, and the surface of boron particles is most likely the hottest emitter, hence the measurement is indeed biased towards the particle surface temperature (Chintersingh et al., 2018). Next, a control experiment of laser irradiation on a pure tungsten base plate was carried out. Before and after the laser irradiation, the spectrometer did not detect any spectral signal fluctuations, thus the influence of tungsten base plate on the spectral signal can be ignored.

The stationary flame surrounding the agglomerates and the condensed boron oxide droplets around the flame affect the spectral intensity detected by the spectrometer. In addition, the spectral emissivity is likely to change substantially during the physicochemical reactions on the particle surface. Since data for these changes are not available, the corresponding changes in spectral emissivity were ignored.

The continuous spectra in the 600-800 nm, which has relatively weak emission peaks for boron combustion intermediates, are used to calculate the temperature. Planck's law can be written in the following form:

$$\ln\left(\frac{I_\lambda \lambda^5}{\varepsilon_\lambda C_1}\right) = -\frac{C_2}{\lambda T}$$

where I_λ is the light intensity, λ the wavelength, ε_λ the emissivity of the emitter, T the temperature, C_1=3.7419E-16W·m^2, and C_2=1.4388E-2m·K, thus the particle temperature can be obtained by calculating the slope of the line formed by $\ln(I_\lambda \lambda^5/\varepsilon_\lambda)$ vs. $1/\lambda$.

The values of the temperature curves were obtained by averaging the three calculation results, with the error range found to be within 50 °C.

Taking the combustion of agglomerated boron in the atmosphere of 20% O_2 + 80% CO_2 as an example, the time of laser initiation is recorded as 0 ms. Fig. 2 shows the temperature fitting curves at 10 ms, 140 ms, and 280 ms.

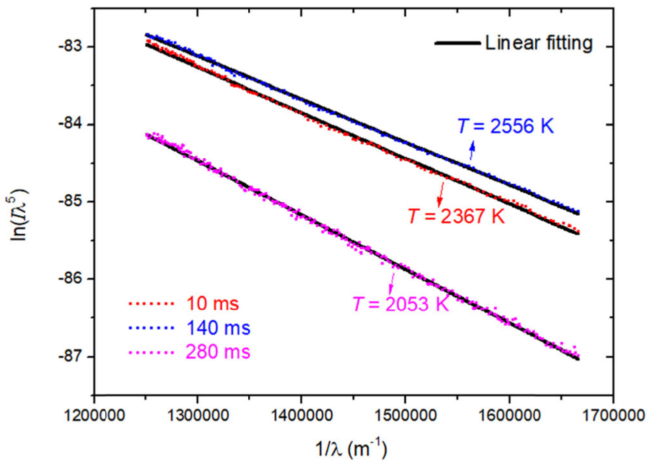

Fig. 1 Fitting to the combustion spectra based on the Planck law at 10 ms, 140 ms, and 280 ms

References

Chintersingh KL, Schoenitz M, Dreizin E, Combustion of boron and boron–iron composite particles in different oxidizers, Combustion and Flame, 192 (2018) 44-58.

Weismiller MR, Lee JG, Yetter RA, Temperature measurements of Al containing nano-thermite reactions using multi-wavelength pyrometry, Proceedings of the Combustion Institute, 33 (2011) 1933-1940.