Development of a translational-rotational temperature measurement method of shock-induced CN radicals

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Recent impact experiments show that an obliquely impacted material actively react with a thick (~1 bar) ambient atmosphere due to intense aerodynamic interactions [1, 2]. Then, a large amount of high-temperature stable diatomic molecules, such as CN and C_2, may produce when the impactor is carbon-rich material. Such a radical production process and subsequent chemical reactions between impact-induced hot radicals and an ambient atmosphere may play an important role in the evolution of surface environments of the Earth (intense radiation [1, 2] and production of prebiotic molecules [3]). However, these processes have not been understood well.

Temperature is a key parameter on estimation of the yield of final products from impact-induced chemical reactions. Cyanide radicals (CN) is one of the most important diatomic molecules for temperature measurement by emission spectroscopy because its emission efficiency is extremely high and it is stable at high temperatures regardless of the redox state. However, the vibrational state of shock-induced CN radicals is not likely to have Boltzmann distribution because CN may form actively during a spectroscopic observation. In this case, we cannot use a widely used method of temperature estimation for diatomic molecules called spectral-form inversion analysis [e.g., 4].

We developed a new translational-rotational temperature measurement method of shock-induced non-equilibrium CN radicals using the band tails of emission spectra. The translational-rotational state is expected to reach thermal equilibrium even if the vibrational state does not have Boltzmann distribution because characteristic time of translational-rotational relaxation is very short [e.g., 5]. Translational-rotational temperature is also an inportant parameter on chemical reactions because it controls collision probability of gaseous particles. The proposed method has two advantages. First, this method is not affected by self-absorption sensitively. Second, it does not require as high wavelength resolution than other methods. Thus, our method is expected to be more suitable for high-speed temperature change measurement, in which high wavelength resolution measurement is difficult.

To investigate a validity of the proposed method, we carried out laser ablation experiments within N_2-H_2O-CO_2-Ar atmospheres using graphite targets and measured the translational-rotational temperature of laser-induced CN and C_2 radicals using our method. The obtained translational-rotational temperatures exhibit reasonable trend as a function of beam cross section, intensity, and time. These results strongly suggest that our method is a powerful tool for translational-rotational temperature estimation of shock-induced non-equilibrium CN radicals.

References

[1] Sugita, S & P. H. Schultz, *JGR*, **108**, E6, 5051, doi:10.1029/2002JE001959, 2003.
[2] Sugita, S & P. H. Schultz, *JGR*, **108**, E6, 5052, doi:10.1029/2002JE001960, 2003.
[3] Kurosawa, K. et al., *LPSC*, **39**, #1629, 2007.
[4] Arnold, J. O. et al., *JQSRT*, **9**, 775-798, 1969.
[5] Zel'dovich Y. B. & Y. P. Raizer, Academic, San Diego, Calif., 1967.