Importance of 10Be as a key indicator of (solar) cosmic ray irradiation in the early solar system

*Hajime Hiyagon[1], Yuuki Tanimura[1], Tomoya Nakamura[1], Kohei Fukuda[3], Wataru Fujiya[4], Naoji Sugiura[1], Takanori Kagoshima[2], Naoto Takahata[2], Yuji Sano[2]

1. Graduate School of Science, The University of Tokyo, 2. Atmosphere and Ocean Research Institute, the University of Tokyo, 3. Department of Geoscience, University of Wisconsin-Madison, 4. College of Science, Ibaraki University

Beryllium-10, which decays to ^{10}B with a half-life of 1.4 Myr, is produced mainly by spallation reactions of solar system materials induced by solar or galactic cosmic rays, but not by thermonuclear reactions in stars. Possible existence of ^{10}Be in the early solar system materials, therefore, has significant importance in considering irradiation processes near the early Sun or in the molecular cloud [1].

Excesses in ^{10}B correlated with Be/B ratios in a number of CAIs from CV chondrites [2-9] suggest the presence of live ^{10}Be at the time of CAI formation. The inferred initial ^{10}Be/^{9}Be ratios are mostly within the range of (0.5-1) x 10^{-3}, though the data are restricted to coarse-grained CAIs from CV chondrites. Recent studies including small CAIs from CH/CB chondrites [10-12] show that the initial ^{10}Be/^{9}Be ratios may be much higher and more variable (from ~10^{-4} to ~10^{-2}), suggesting that the origin of ^{10}Be in CAIs is spallation reactions induced by solar cosmic rays.

Data for chondrules are scarce. Sugiura (2001) [13] analyzed anorthite in chondrules from the Y82094 (ungrouped C3.2) chondrite and found a possible correlation between ^{10}B excesses and Be/B ratios, but the results are not conclusive due to relatively large errors. We further conducted Be-B isotope analyses for chondrules in Y82094 chondrite using NanoSIMS at the Atmosphere and Ocean Research Institute, The University of Tokyo [14]. Resolvable excesses in ^{10}B are found in some of the Y82094 chondrules, but ^{10}Be was probably not alive at the time of the chondrule formation. Some carriers of excess ^{10}B are required in the precursor materials of these chondrules.

Here we review recent progress in Be-B isotopic studies and discuss their importance in understanding the irradiation processes in the early solar system. We will also show our some new results on Be-B systematics for chondrules from Y82094 (C 3.2) and NWA7936 (LL 3.15) chondrite.

References

[1] Chaussidon M. and Gounelle M. (2006) in *Meteorites and the Early Solar System II*, pp. 323-339. [2] McKeegan K. D. et al. (2000) *Science*, 289, 1334-1337. [3] Sugiura N. et al. (2001) *Meteoritics & Planet. Sci.*, 36, 1397-1408. [4] MacPherson G. J. et al. (2002) *Geochim. Cosmochim. Acta*, 67, 3165-3179. [5] Chaussidon M. et al. (2006) *Geochim. Cosmochim. Acta*, 70, 224-245. [6] Wielandt D. et al. (2012) *Astrophys. J. Lett.* 748, L25-L29. [7] Srinivasan G. and Chaussidon M. (2013) *Earth Planet. Sci. Lett.,* 374, 11-23. [8] Liu M. C. et al. (2009) *Geochim. Cosmochim. Acta*, 73, 5051-5079. [9] Liu M. C. et al. (2010) *Astrophys. J. Lett.*, 719, L99-L103. [10] Gounelle M. et al (2013) *Astrophys. J. Lett.*, 763, L33-L37. [11] Fukuda et al. (2017) *80th Ann. Meeting of the Meteoritical Society* (Abstract) #6210. [12] Fukuda et al. (2019) *Astrophys. J.* (submitted). [13] Sugiura N. et al. *Lunar and Planetary Science* XXXII, Abstract #1277, 2001. [14] Hiyagon et al. (2018) *NIPR Symposium on Antarctic Meteorites* (Abstract).

Keywords: Beryllium-10, early solar system, cosmic ray, irradiation, CAIs, chondrules