Abiotic formation of amorphous carbonaceous particles by a HMX (cyclotetramethylenetetranitramine) explosion experiment: implication from organic matter and the quench effect

Y. Takano[1], K. Yamada[2], T. Saiki[3], M. Hayakawa[3], H. Imamura[3], M. Abe[3], K. Tanaka[4], M. Arakawa[5], T. Nakamura[6], H. Sugahara[1], R. Okazaki[7], T. Sawada[3] and S. Tachibana[8]
[1]Japan Agency for Marine-Earth Science & Technology (JAMSTEC), [2]Tokyo Institute of Technology (TIT), [3]Japan Aerospace Exploration Agency (JAXA), [4]National Institute of Advanced Industrial Science & Technology (AIST), [5]Kobe Univ., [6]Tohoku Univ., [7]Kyushu Univ., [8]Hokkaido Univ.
E-mail: takano@jamstec.go.jp.

HMX (putative High-Melting Explosive; i.e., cyclotetramethylenetetranitramine; chemical composition, $C_4H_8N_8O_8$; molecular weight, 296.15) is one of typical high explosives for producing momentary driving force and is used for Small Carry-on Impactor (SCI), a scientific instrument for an artificial cratering experiment in the Hayabusa-2 mission [1]. To demonstrate the explosion product including from other compensate combustion chemicals, we conducted a simulation experiment of HMX-based explosion together with HTPB (Hydroxyl Terminated Polybutadiene), IDP (Isodecyl palargonate; $C_{19}H_{38}O_2$) and IPDI (Isophorone diisocyanate; $C_{12}H_{18}N_2O_2$) under Ar atmosphere, ambient temperature and pressure. After the explosion in the closed experimental box, we collected the gaseous sample, carbonaceous solid products and relic of burst metal materials.

Firstly, morphological properties of solid carbonaceous particle products were observed by Scanning Electron Microscope coupled with Energy Dispersive X-ray Spectroscope (SEM-EDX). The analysis revealed rapid melting process of metal by the HMX-based explosion and re-crystalized precipitation during the quench effect. The size distribution of amorphous particles were approximately 1-100 μm scale. We also confirmed carbonaceous / metal complex products containing initial metal components (e.g., Al, Cu, Fe, Cr). For further validation and feedback to the operation [1], the carbon and nitrogen isotopic compositions of the solid carbonaceous particles were determined by an isotope ratio mass spectrometer.

Secondly, the volatile components were analyzed by a solid-phase micro-extraction (SPME) coupled with gas chromatography/mass spectrometry (GC/MS). Wide variety of volatile compounds including aliphatic and aromatic carbon structures were detected. The functional groups of the products showed hydroxyl, aldehyde, nitrile, carboxyl and other labile groups. We also confirmed the abiotic formation of involatile amino- and N-heterocyclic compounds extracted from the carbonaceous particles. Consequently, we suggest that the HMX-based explosion nucleus was exposed to momentary high temperature (cf. melting point of metal materials; Cu, 1084^{o}C; SUS304, 1400-1450 ^{o}C), whereas the quench effect would abiotically produce the various labile organic matters without thermal degradation processes.

[1] Tachibana, S., Abe, M., Arakawa, M., Fujimoto, M., Iijima, Y., Ishiguro, M., Kitazato, K., Kobayashi, N., Namiki, N., Okada, T., Okazaki, R., Sawada, H., Sugita, S., Takano, Y., Tanaka, S., Watanabe, S., Yoshikawa, M., Kuninaka, H. and Hayabusa project team (2014) Hayabusa-2: Scientific importance of samples returned from near-Earth C-type asteroid 1999 JU_3. Geochemical Journal, submitted.