Survival of organic materials during atmospheric entry of micrometeorites

*Masayuki Uesugi[1], Motoo Ito[2], Naotaka Tomioka[2], Yu Kodama[3], Takuji Ohigashi[4], Hayato Yuzawa[4], Kentaro Uesugi[1], Akira Yamaguchi[5], Naoya Imae[5], Naoki Shirai[6], Yuzuru Karouji[7], Aiko Nakato[7], Kasumi Yogata[7], Kaori Hirahara[8], Ikuya Sakurai[9], Toru Yada[7], Masanao Abe[7]

1. Japan synchrotron radiation research institute, 2. Kochi institute for Core Sample Research JAMSTEC, 3. Marine Works Japan Ltd., 4. UVSOR Institute for Molecular Science, 5. National institute of Polar Research, 6. Tokyo metropolitan university, 7. Japan aerospace exploration agency, 8. Osaka University, 9. Nagoya University

Organic compounds in extraterrestrial materials are thought to be one of the important components for the building block of Earth, especially for the origin of life. It is considered that those organic materials would be transported to the Earth by micrometeorites, because previous studies suggested that the flux of micrometeorite to the Earth is much larger than that of meteorites (5.38 x 10^4 kg/y for meteorites and 4 x 10^7 kg/yr for micrometeorites) [1-2]. In addition, micrometeorites show distinct feature that their composition is rather similar to carbonaceous chondrites than ordinary chondrites [3]. Thus, micrometeorites should be an important carrier for the organic materials from interplanetary space to the earth. It is well known that the micrometeorites heated up to 2000 degree Celsius during the atmospheric entry, due to frictional heating. During such intense heating under the oxidized condition, organic compound would be modified and/or destructed. It is important to evaluate the effect of heating of organic compounds during the atmospheric entry, to investigate origin and evolution of terrestrial organics.

In April of 2019, the Hayabusa2 spacecraft succeeded in the sampling of regolith materials from surface of the asteroid Ryugu, which is classified to C type asteroid and considered to be a parent body of carbonaceous chondrites. The sample would contain organic materials those free from the effect of heating during atmospheric entry and even free from terrestrial contamination or weathering. The Phase2 curation team Kochi started the rehearsal analysis of the Hayabusa2 returned samples, using Antarctic micrometeorites (AMMs)[4-5], and found that amount of organic nano-globules survived in the AMMs larger than 150 μm, those would have experienced intense heating during atmospheric entry due to large moment of inertia. Numerical calculations showed that such AMMs would have heated higher than 1000 degree Celsius, and also showed that ram pressure during the heating is almost equivalent to 1 atm.

In order to investigate the possibility of survival of organic matters in intense heating, we conducted heating experiment of carbonaceous meteorites at 1 atm, and evaluate the effect on the organic materials using scanning transmission x-ray microscopy and near edge x-ray absorption fine structure (STXM-NEXAFS) analysis. Results of the experiments show that organic materials are easily destructed in oxidized condition even by short-term heating, and are robust against heating for reduced environment.

We can examine the conditions of atmospheric entry of the micrometeorites by comparing the structural features of organic materials in extraterrestrial materials (e.g. the Hayabusa2 returned samples and AMMs), with experimental products, and would give important constraints on the evolution of organic matters in early Earth or primitive terrestrial environment.

References:

[1] Yada T. et al. (2004) The global accretion rate of extraterrestrial materials in the last glacial period estimated from the abundance of micrometeorites in Antarctic glacier ice, Earth. Planet. Space, 56:67-79.

[2] Zolensky M. et al. (2006) Flux of extraterrestrial materials, in Meteorites and the early solar system II, pp. 869-888.

[3] Imae N. et al. (2013) Micrometeorite precursors: Clues from the mineralogy and petrology of their relict minerals, Geochim. Cosmochim. Acta, 100:116-157.

[4] Ito M. et al. (2020) The Ryugu Grain Analysis: Approach by the Phase 2 Curation "Team Kochi", 82nd Annual Meeting of The Meteoritical Society, held 7-12 July, 2019 in Sapporo, Japan. LPI Contribution No. 2157, 2019, id.6082

[5] Uesugi M. et al. (2020) Preparation for the analysis of Hayabusa2 returned samples, 82nd Annual Meeting of The Meteoritical Society, held 7-12 July, 2019 in Sapporo, Japan. LPI Contribution No. 2157, 2019, id.6269

Keywords: micrometeorite, organic materials, atmospheric entry

