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Infrared and raman spectroscopic analyses of the chondritic organic matter shot into silica aerogel by impact experiment

Yuichiro Ogata[1*], Hikaru Yabuta[1], Satoru Nakashima[1], Kyoko Okudaira[2], Taro Moriwaki[3], Yuka Ikemoto[3], Sunao Hasegawa[4], Shinichi Yokobori[5], Hajime Mita[6], Kensei Kobayashi[7], Eiichi Imai[8], Hirofumi Hashimoto[4], Makoto Tabata[4], Yuko Kawaguchi[5], Tomohiro Sugino[5], Hajime Yano[4], Masamichi Yamashita[4], Akihiko Yamagishi[5], TANPOPO Working Group[4]

[1]Osaka University, [2]University of Aizu, [3]JASRI/SPring-8, [4]ISAS/JAXA, [5]Tokyo University of Pharmacy, [6]Fukuoka Institute of Technology, [7]Yokohama National University, [8]Nagaoka University of Technology

Introduction:It has been suggested that sources of the prebiotic organic molecules were delivered to the early earth by meteorites, comets, and cosmic dusts (Exogenous delivery) (Chyba and Sagan, 1992). It is important to unravel the compositions and structures of organic matter in the small primitive bodies for better understanding the origin and chemical evolution of the prebiotic molecules in space. Although indigenous organic matter in meteorites and cosmic dusts has been known to be well preserved, some could be heated and lost during atmospheric entry or exposed to contamination from terrestrial materials. In order to collect the astromaterials without these problems, the cosmic dust collection with ultralow-density silica aerogel placed on International Space Station is planned (TANPOPO mission). However, the possible alteration of organic matter by impact heating upon aerogel capture is an unsolved issue. In this study, the high velocity impact experiment of meteorite powders was conducted for the purpose to evaluate the possible alteration of organic molecular compositions of meteorites before and after the impact.

Experimental:One hundred micron-sized Murchison meteorite powders were shot into silica aerogel by the impact velocity of 4km/s, using the two-stage light gas gun at Space Plasma Laboratory, ISAS, JAXA. The meteorite particles penetrated into the aerogel were carefully picked up by tungsten needle and fine brush, sandwiched with two Al plates, and hand-pressed. For comparison, non-shot Murchison meteorite powders were prepared on the Al plates as well. These shot- and non-shot- Murchison samples were analyzed by micro-FTIR (JASCO, FTIR-620) and micro-Raman spectroscopes, respectively. In addition, infra-red imaging of the shot Murchison particles was conducted by the high brilliance micro-FTIR (Bruker, IFS120HR), BL43IR, Spring-8. Step size is 10 micro metre, mode of measurement is reflection, wavenumber resolution is 4cm^{-1}.

Results and discussion:In the micro-FTIR spectra of the three shot Murchison particles, the peaks assigned to aliphatic carbon (3000, 2900, 2880cm^{-1}), aromatic carbon (1600cm^{-1}), and SiO (1100cm^{-1}) were identified. The infra-red imaging detected the local regions where aliphatic and aromatic carbons and SiO are abundant, respectively, from the particles. The distributions of aliphatic and aromatic carbons were very similar, but not completely overlapped. One of the two SiO-rich regions was almost consistent with the organic-rich region while another was not. In general, aliphatic carbon in carbonaceous chondrites has been known to be depleted by heating (Yabuta et al.2005). Detection of aliphatic carbon from the shot Murchison particles in this study implies that organic matter in the particles is not highly altered by the impact velocity of 4km/s.

In the Raman spectra of the three shot Murchison particles, from which organics were identified by micro-FTIR, D- (˜1350cm^{-1}) and G- (˜1580cm^{-1}) bands were detected. The peak positions and widths of D- and G-bands for the shot Murchison particles were similar to those for the non-shot- Murchison particles. Thus, again, it is unlikely that organic matter in Murchison particles is altered by the impact experiment. The G-band positions and widths for the shot Murchison particles were similar to those for insoluble organic matter from Murchison meteorite (Busemann et al. 2007). However, their D-band positions and widths were different, which is probably due to the difference of analytical conditions. Organics were not detected from the other four particles by infrared nor Raman. This may be because the volatile components in meteorites were partially vaporized or moved due to the impact heating. Further investigation will be necessary to improve the feasibility of the cosmic dust analyses s collected in TANPOPO mission.

Keywords: meteorite, cosmic dust, impact heating, infrared spectroscopy, Raman spectroscopy, TANPOPO mission