Design of space exposure experiments of organic matter in Tanpopo 2

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1. Introduction

Large number of organic compounds have been discovered in molecular clouds and in meteorites. Some of organic compounds required for emergence of life are thought to be synthesized in space. Then, meteorites and interplanetary dust particles could deliver them to the Earth. The first Japanese astrobiology space experiment called “Tanpopo” was conducted to study this hypothesis[1].
The objective of the Tanpopo Mission is to understand bi-directional propagation of microorganisms and organic matter between the Earth and space. In other words, in the Tanpopo Mission, we examine whether life exists only on the earth by evaluating whether microorganisms can escape into space and whether organic matter can reach to the Earth from outer space.
As one of subthemes in this project, amino acids and their precursor compounds including complex interstellar organic matter analog were directly exposed to outer space by utilizing the International Space Station (ISS), and recoveries of these organics were measured to understand degradation of organic compounds under the environment of the outer space. In the Tanpopo experiment, hexatriacontane (HTC) was used to prevent the sample from sublimation during exposure to space at the ISS. However, HTC absorbs ultraviolet light with a wavelength of 160 nm or less. To understand the effects of shorter wavelength UV, the next space experiment "Tanpopo 2" applies a new design for direct exposure of organic compounds without HTC and optical windows. In addition to the aluminum plate same as the one used in Tanpopo, the silicon substrates are also used for exposure the sample to space, in the organic matter exposure experiment of “Tanpopo 2 “. In the Tanpopo Mission, glycine, hydantoin, isovaline, ethylmethylhydantoin, CAW (complex organic matter produced from proton beam irradiation to CO, NH_3, H_2O mixture) were used, and glycine and CAW showed relatively high recoveries [2]. In "Tanpopo 2", glycine and CA (proton beam irradiation product to CO, NH_3 mixture) on the silicon substrates will be directly exposed to space in addition to the same compounds on the same aluminum plate used in the Tanpopo. The recovered samples will be analyzed by FT-IR, XANES, and SEM, in addition to amino acid analysis.
Here we report the design of the space experiment such as preparation method of the space experiment sample.

2. Experimental

(1) A gas mixture of CO (350 Torr) and NH_3 (350 Torr) and a silicon plate (10 mmϕ) were placed in a glass container, and the gas mixture was irradiated with 2.5 MeV proton beam from a tandem accelerator to deposit organic matter on the plate.
(2) The thickness of the organic matter (CA) film on the silicon plate was measured using a three-dimensional microscope.
(3) Structural analysis of organic matter (CA) on the silicon plate was also carried out using FT-IR.
(4) Amino acid analysis was carried out by cation exchange HPLC after hydrolyzing silicon plate with CA with 6 M hydrochloric acid at 110 °C for 24 hours.

(5) Glycine is planned to be deposited on a silicon substrate by a vacuum vapor deposition equipment (Fukuoka Institute of Technology).

3. Results and Discussion

The CA deposition thickness was approximately 8 μm, but more sample thickness would be required due to potential loss of the organic materials by atomic oxygen present in low Earth orbit during exposure. Thus, we decided to use non-polished Si substrates instead of polished Si substrate. Because the sample can be kept in the bottom of indentations on the rough surface of non-polished substrate, even if a part of sample surface is lost.
Amino acid analyses of CA by cation exchanged HPLC showed, various amino acids including aspartic acid, threonine, glycine, alanine, -aminoisobutyric acid and serine were detected after acid hydrolysis. Glycine was particularly abundant, whose yield was 827 ±7 nmol from a single CA deposited Si substrate.

4. Conclusions

We will conduct the durability test of our samples on the silicon substrate including the vibration test, cooling test, heating test before launch in 2019 with the space X company to the ISS. We are planning to conduct various analyses from recovered samples. The recovery and degradation of these samples will make a further leap forward our understanding of the possible delivery of organic matter from interplanetary dust particles to the early Earth.

5. References

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