窒素ガス中飛翔体衝突により発生する高温ガスプルームにて合成される アミノ酸等有機分子の研究

Synthesis of amino acids and organic molecules in hot gas plume generated by an impact in nitrogen gas

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Abstract As simulation experiment of impact synthesis of organic molecules by asteroids in space, the impact experiment under nitrogen-gas atmosphere by use of a 2-stage gas-gun was carried out. A hot gas plume after the impact was observed by a high-speed camera. The synthesized gas species are in-situ measured by a Q-mass spectrometer. The generated carbon soot is carefully analyzed by the HPLC method, LD-TOF-MS method, and EDS of STEM method. It is confirmed that many amino acids are synthesized by the impact. And the analysis data are in good agreement with a theoretical reaction model in the hot gas plume.

1 Introduction

We are interested in origin of life and living things in extra-solar stars. [1] By the astrophysics studies and earth science study, our life started around 4 billion years ago on the primitive earth after the heavy impact phenomena. By the hypotheses of Panspermia, microscopic life-forms came to Earth in this old ages. It has been studied that asteroid's impacts or high-energy proton beams made surface reactions on Earth and huge amount of organic molecules were synthesized. [2, 3] Earth scientist are studying about organic reactions near hydrothermal deposits under deep sea, and many kinds of organic molecules have been synthesized there. Now, it is difficult to confirm the history of generation of life on Earth. However, many possibility of the root to the origin of life should be studied.

Here, we have a hypothesis that amino acids and other organic molecules have been synthesized by asteroid's impact onto planets/satellites. Especially, on planets/satellites with nitrogen atmosphere like Titan satellite, we can expect hog-gas-reaction by asteroid's impacts. And products by the impacts have been stored on cool and dark surfaces. In order to simulate the hypothesis, impact experiment by use of a gas-gun has been carried out. [4] The evolution of the hog gas plume is observed, synthesized gas species are analyzed by a mass spectrometer, and synthesized carbonaceous soot is chemically analyzed.

2 Experimental setup and methods

The impact experiment was carried out at ISAS/JAXA, Sagamihara using a two-stage gas gun. [5] a polycarbonate ball, 7.2 mm in diameter hits a target in a target chamber. Here, a small pressurized chamber is set at the end of the target chamber. A projectile penetrates an aluminum foil at an orifice of the pressurized chamber, and hits an iron target, on which ice or ice + hexane can be set. The target can be cooled by liquid nitrogen to less than 200 K. The impact phenomenon can be recorded by a high speed camera (Shimadzu Co, HPV-X). The synthesized gas species are sampled and measured by a Q-mass spectrometer (Pfeiffer Vacuum Co., PrismaPlus). Clear aluminum sheets are set on the inner surface of the chamber, and synthesized soot deposits on the sheet. After the Impact, the soot is carefully collected and analyzed by a HPLC (JUSCO Co., Gulliver System) after hydrolysis and dabsyle reactions. [4] And an EDS of STEM (JEOL Co., JEM-1400) and a LD-TOF-MS (Bruker Co., autoflex) are used. To protect contaminations, all the glass tools were baked at 500 °C for 3 hours.

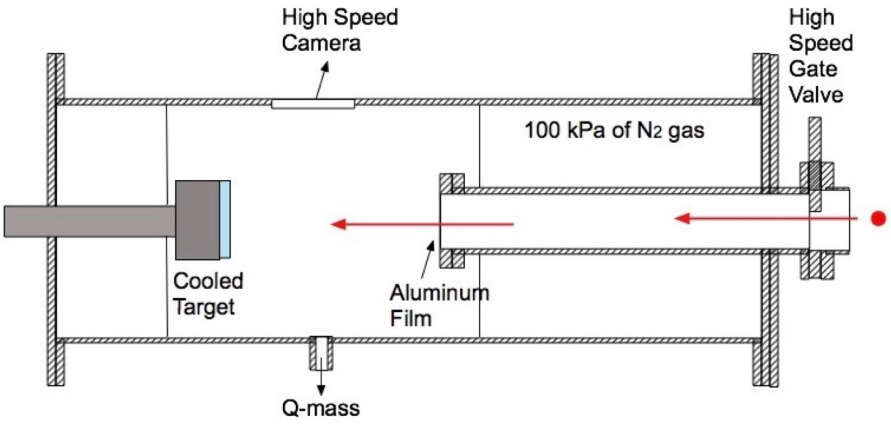

Fig.1 Schematic of the pressurized chamber with a target and a Q-mass spectrometer.

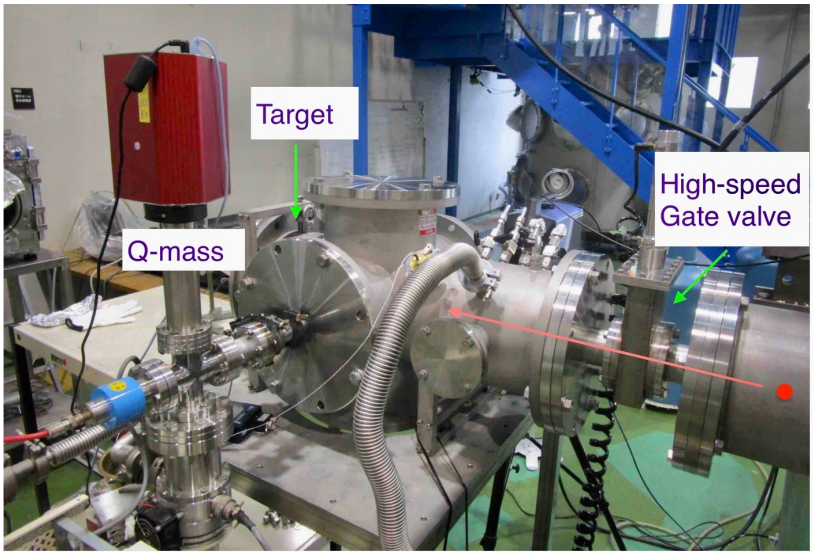

Fig. 2 A photo of the pressurized chamber.

3 Experimental results

3-1) Images of the hot gas plume

The impact phenomenon is recorded by a high-speed camera from horizontal direction. Figure 3 shows the hot gas plume after the impact (t= 10 μs and t= 24 μs). It glows and emits light for about 30 μs. We could observe particle clouds in the plume during the cooling process.

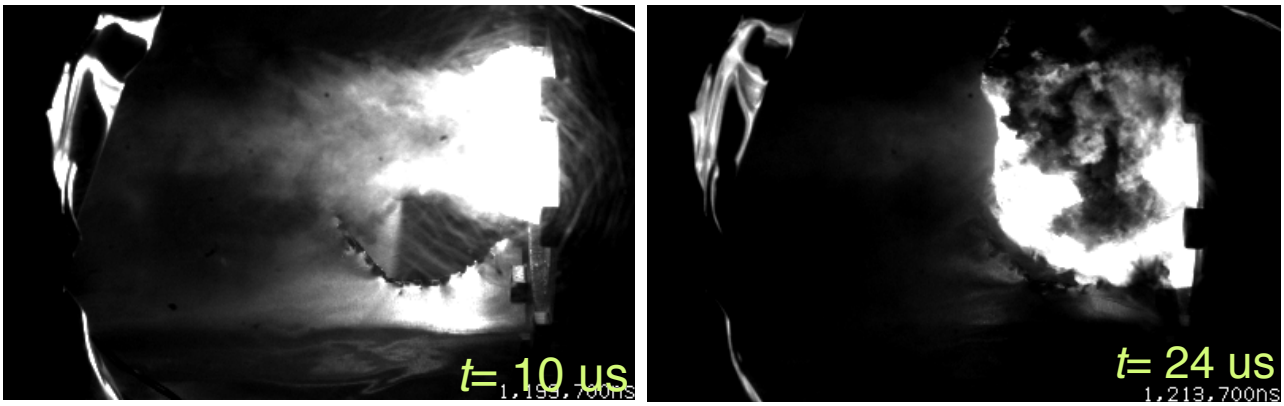

Fig. 3 Profile images of the hot gas plume after the impact. The left end is the entrance orifice and the right end is the target.

3-2) Q-mass measurement

After the impact a main gate valve is immediately closed and a small gate valve for the Q-mass is opened to sample the gas in the pressurized chamber. Comparing with the background gas species, synthesized molecules can be identified. When an ice + iron target is used in 100 kPa of N_2 gas, synthesis of molecules, M= 26 (CN or C_2H_2), M= 27 (HCN or C_2H_3), M= 30 (NO or C_2H_6) are detected. Instead of normal ice, heavy water ice is used on the target, by which same-mass molecules are detected (M= 26, 27 and 30). It is conjectured that CN, HCN and NO molecules are synthesized. As clear peaks of M> 50 are not detected in this experiment, we will increase the sensitivity and try to measure them again.

3-3) Hydrolysis and HPLC measurement

The deposited carbon soot on the aluminum sheets are carefully collected and a part of the sample is hydrolyzed using hydrochloric acid for 24 hours. Then the sample is filtered and condensed. The sample is dabsylized and analyzed by the HPLC. Figure 4 shows a typical HPLC chart in case of the hexane+ ice + iron target. [6] Several amino acids are confirmed. Figure 5 shows the estimated content of each amino acid per 1 mg of the soot, which is estimated from Fig. 4.

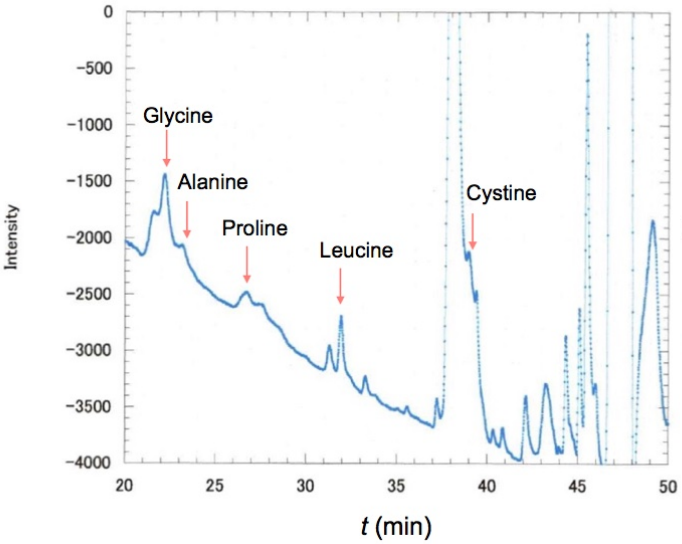

Fig. 4 HPLC chart of solvent after hydrolysis and filtering. A hexane+ice+iron target is used.

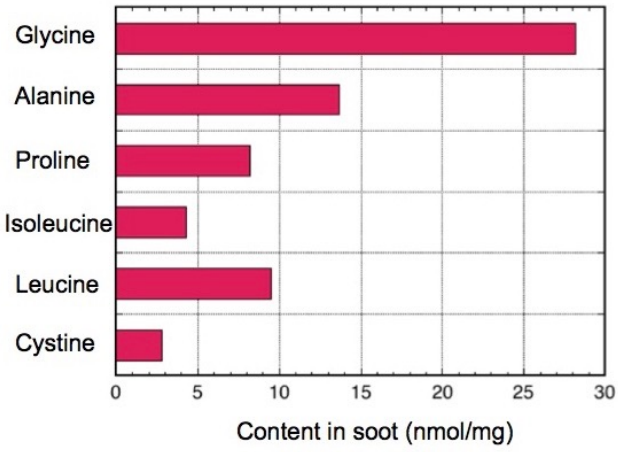

Fig. 5 Content of amino acid per 1 mg of soot, which is estimated from Fig. 4.

3-4) LD-TOF-MS measurement

The collected sample is mixed with pure 2-propanol (matrix) and the mass is measure by the LD-TOF-MS.

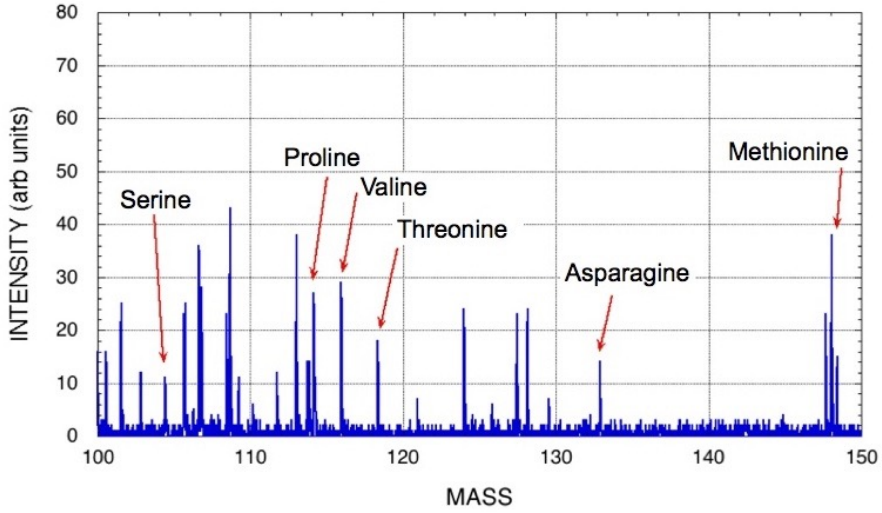

Fig. 6 A LD-TOF-MS spectrum of the soot. (An ice + iron target, 2-propanol matrix, + ion mode, 50 shots averaged.)

Figure 6 shows a typical mass spectrum. In the many peaks, peaks corresponding to amino acids are included. By HPLC, TOF-MS and other analysis methods, synthesized species will be confirmed.

4 Discussion and summary

After the impact, a hot gas plume is generated. It grows and extinct. During this process, many radical species are synthesized and react each other and stabilize. We conjecture that the reaction processes are stochastically, and many kinds of amino acids and organic molecules can be synthesized. From the experiment, generation of C_2, CN and CH radicals are confirmed by spectroscopic measurement, by which we can expect the reaction; $C_2 + N_2 \rightarrow 2CN$. [7] From the HPLC and TOF-MS analyses, synthesis of CN, NH_2, CH and COOH radicals is expected.

However, major products in the impact reactions are carbon nano-particles. During the cooling process of the plume, many nano particles are produced. On the nano particles, many radicals attach and react each other. Therefore, it can be conjectured that, as the synthesis processes of amino acids, both the gas-phase reactions and the surface reactions are important. Now we are going to study to make clear the reaction processes.

As summary:

1) We believe that the impact reactions in space are important processes to synthesize amino acids in space.
2) Many kinds of amino acids are detected. And many radicals are expectedly generated in the hot gas plume after the impact. We are studying about the reaction processes.
3) Generation of CN radicals is important to synthesize amino acids.
4) Generation of nucleic acid bases, and optical isomers of amino acids should be studied near future. [8-10]

Acknowledgements

This study was supported by Grant-in-Aid for Scientific Research (C) of MEXT. This study was supported by ISAS/JAXA Space Plasma Cooperative Program.

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