Measurement of hot plume and analysis of carbonaceous products made by the impact experiment in nitrogen gas

窒素ガス中衝突実験における高温プルームの測定と合成炭素化合物の分析

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Abstract In order to investigate impact production of carbonaceous products by asteroids on Titan and other satellites and planets, simulation experiment is carried out using a 2-stage light gas gun. A small polycarbonate bullet (a metal bullet) with about 6.5 km/s is injected into a pressurized target chamber filled with 1 atm of nitrogen gas, to collide with a water + iron target (an iron target or a water +hexane + iron target). Strong emissions of CN and C_2 molecules are measured, and CN rotational temperature is evaluated. From the produced black soot, production of amino acids is measured by an HPLC, resulting in detection of remarkable amount of amino acids from the soot.

1. Introduction

We are interested in the impact production of carbonaceous materials on planets and satellites, especially on Titan satellite. [1]. The laboratory simulation experiment has been carried out using a 2-staged light-gas-gun. By the impact reactions under nitrogen atmosphere, we have confirmed production of many types of carbon clusters, like fullerenes, carbon nanotubes, carbon nano-capsules, and balloon-like carbons. [2-5] However, reaction processes in a plume generated after the impact are not clear. Therefore, spectroscopic measurement using a spectrometer, a streak camera, and a high-speed camera is carried out. From these measurements, CN rotation temperature and time variation of emissions in the plume are obtained. In these impact reactions, production of amino acids and nitride polymers is expected. Therefore, we tried to find these products using the HPLC method and the FT-IR method.

2. Experimental

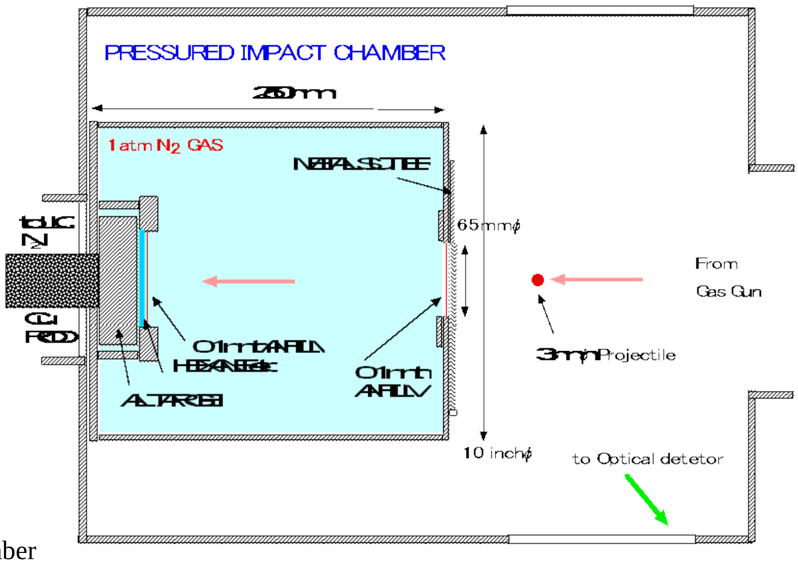


Fig.1 Schematic of the pressurized impact chamber.

The experiment is carried out using a 2-stage light-gas-gun at ISAS/JAXA. [6] This gas gun can accelerate a polycarbonate bullet 7.1 mm in diameter (or a stainless-steel bullet 3.2 mm in diameter) to about 6.5 km/s under a vacuum of 0.1 Pa, and the bullet collides with an ice + iron target (an iron target or an ice + hexane + iron target) in a pressurized chamber. Schematic of the pressurized chamber is shown in Fig. 1. At the end of the large target chamber of the gas gun, the pressurized impact chamber is set, which has 255 mm in diameter and 250 mm long, made of stainless steel. To collect produced soot sample, inside-walls of the chamber are covered with clean aluminum sheets. The pressurized chamber is at first evacuated by a rotary pump, and then 1 atm of nitrogen gas is introduced. A bullet penetrates the aperture of the chamber, 65 mm in diameter covered with a 0.1 mm thick aluminum film, and hits the iron target 76 mm in diameter and 25 mm thick. The target can be cooled down to about -100 C by thermal conduction of a copper rod, which is cooled by liquid nitrogen. On the iron target, thin ice/water (water +hexane) layer about 2 mm thick can be set by covering with a thin aluminum-sheet.

3. Experimental Results and Discussion

3.1) Pressure monitoring

At first, time variation of nitrogen gas in the pressurized chamber is measured by a MEMS-type small pressure sensor (MPS2407, Metrodyne Micro-system Co.) with a bridge-detection circuit, a sensor- head of which is directed toward the inner wall. Figure 2 shows time variation of the nitrogen pressure. The impact makes a quick increase of the pressure, and then the pressure gradually decreases with a time constant of about 60 ms, which is much longer than the plume generation time, and the nitrogen pressure is quasi-constant during the impact reaction.

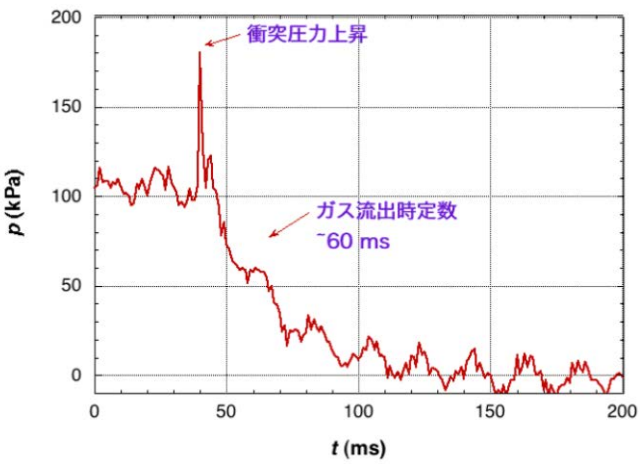


Fig. 2 Time variation of the nitrogen pressure during the impact.

3.2) Molecular emissions and rotation temperature

By using an optical fiber and a spectrometer, molecular emission spectra are observed. The end of optical fiber has a focusing lens, and only an emission from a narrow region 1 cm above the target is measured. Figure 3 (a) shows the spectrum when a polycarbonate bullet hits an iron target. There are strong emissions from CN and C_2 molecules. Same way, Fig. 3 (b) shows emissions when a polycarbonate bullet hits a water + iron target. In this case, CH emission is added. In Fig. 3(c) an iron + ice + hexane target is used. Much different spectrum is obtained

(a) A polycarbonate bullet hits an iron target.

(b) A polycarbonate bullet hits a water + iron target.

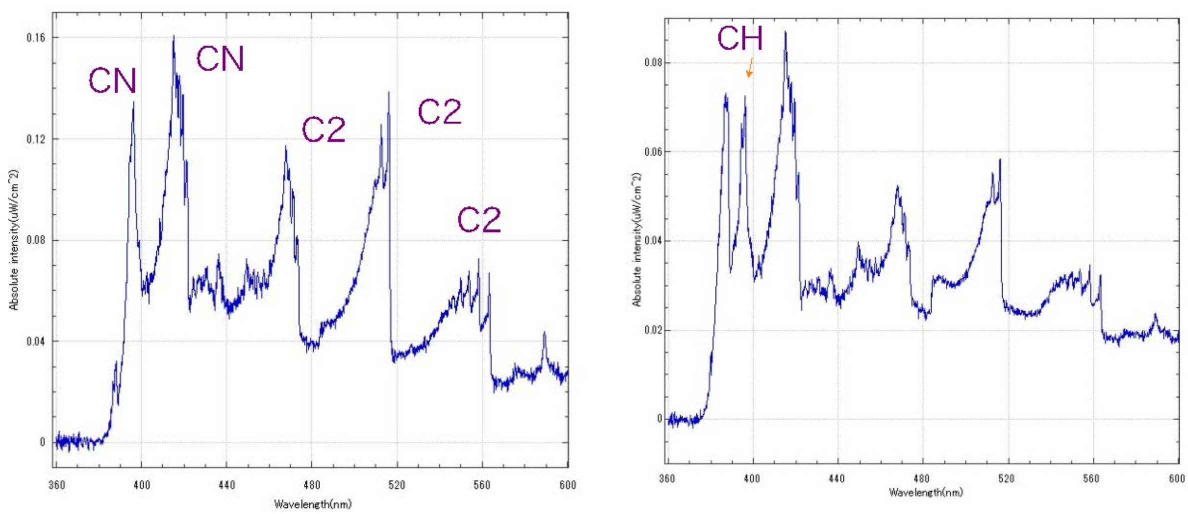


Fig. 3A Time-averaged emission spectra (exposure time of 1.0 s).

(c) A polycarbonate bullet hits a water + hexane +iron target.

(d) A polycarbonate bullet hits an iron target in vacuum.

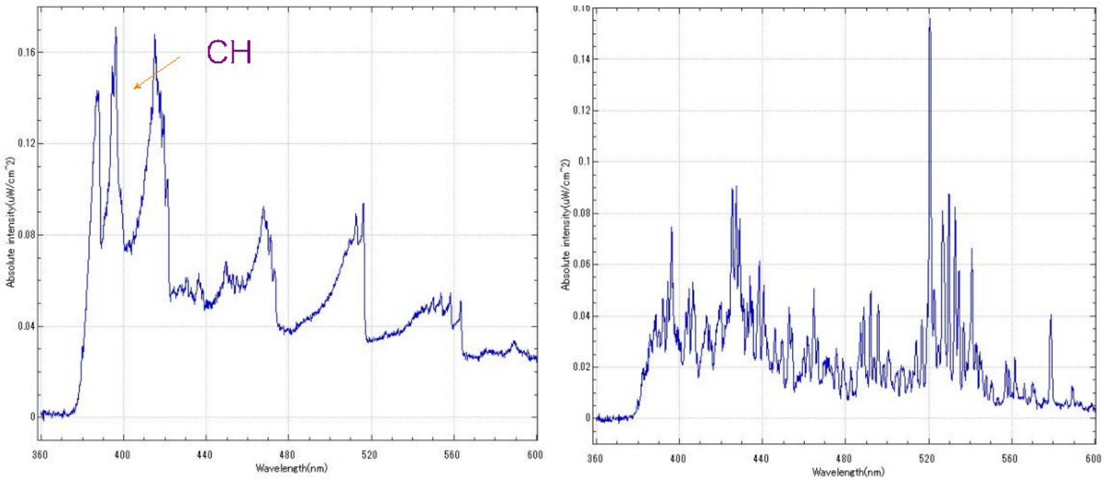


Fig. 3B Time-averaged emission spectra (exposure time of 1.0 s).

when the chamber is in vacuum condition as shown in Fig. 3(d). The molecular emissions are weaker, and atomic emissions are observed. From the simulation software of molecular spectra (LIFBASE, SRI International Co. [7]), theoretical CN spectra for selected temperatures are calculated, and compared with the experimental data as shown in Fig. 4. Then, the CN rotation temperature is evaluated. Figure 5 shows the evaluated CN temperatures for the 4 impact conditions. [8]

3.3) Time variation of the emission spectra

By using a streak camera, time variation of the emission spectrum (for every 2 us) is observed. Figure 6 shows time variation of the emission spectrum when a polycarbonate bullet hits the iron target. From these spectra, CN and C_2 emission intensities as a function of time are obtained as shown in Fig. 7.

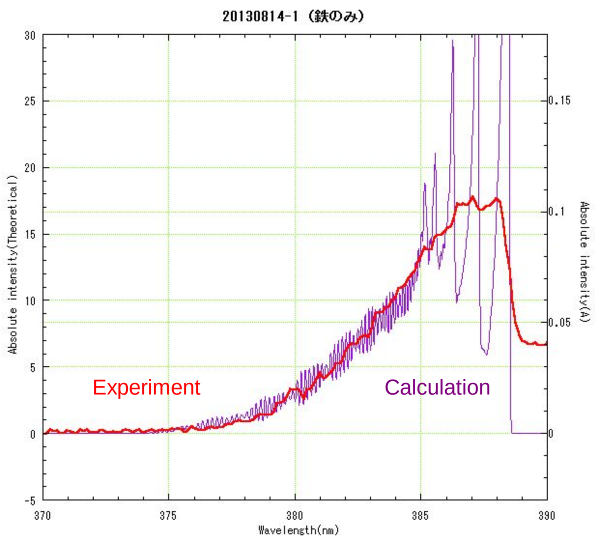


Fig. 4 Comparison of the CN spectrum and the calculated curve (4600 k) to obtain the rotation temperature.

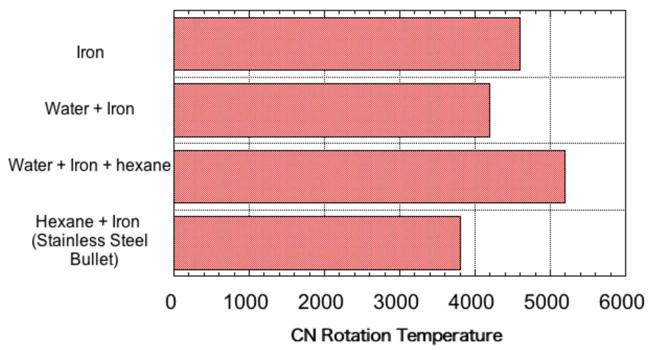
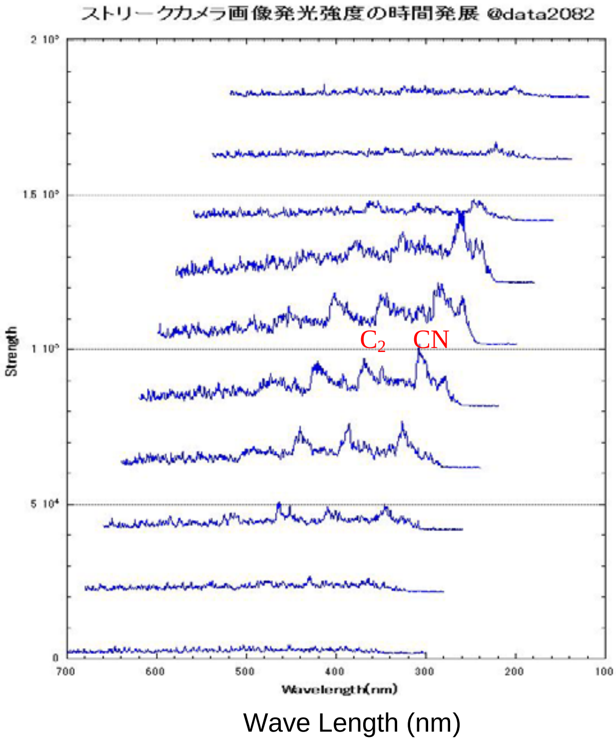


Fig. 5 Evalutated rotation temperatures for the 4 impact conditions.



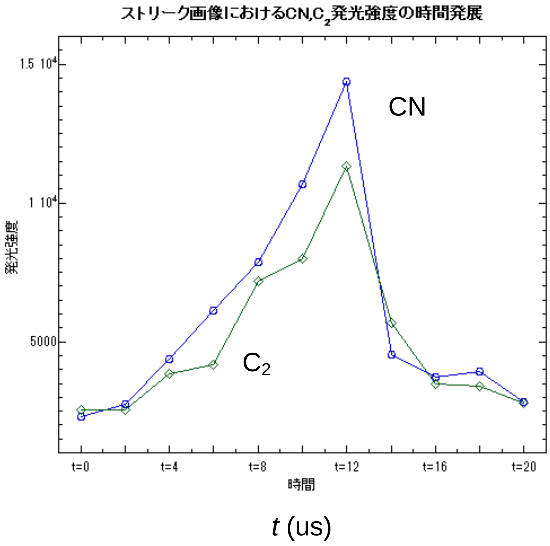


Fig. 6 Time variation of the emission spectrum (every 2 us) obtained by a streak camera.

Fig. 7 Emission intensities of CN and C_2 versus time.

3.4) Detection of amino acids from the produced soot

In order to detect production of amino acids, the produced soot, which is deposited on the inner wall of the pressurized chamber as shown in Fig. 7, is analyzed. A part of the soot is refluxed in pure water, filtered and condensed. The liquid sample is reacted with dabsyl chloride to make dabsyl-amino acids. The reaction mechanism is shown in Fig. 9. [9] And, the produced sample is analyzed by the liquid chromatograph method (Jusco Gulliver System, wave length of 465 nm). The spectra are compared with those of 17 standard amino acids. As a result, about 10 pmol of glycine, and less amount of alanine and proline are found in the sample, when the polycarbonate bullet hits the water + hexane + iron target. In case of the water + iron target and the iron target, less amount of amino acids are found. Cross check of

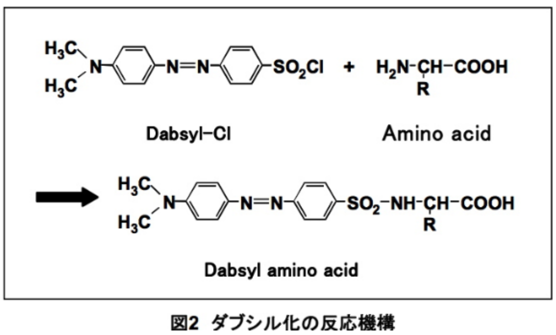


Fig. 8 deposited black soot on an aluminum sheet set on the inner wall of the pressurized chamber.

Fig. 9 Schematic of the dabsyle reaction (quoted from Ref. 9) this impact production is underway using the HPLC, the FT-IR, and the LD-TOF-MS methods.

4. Summary

1) Time variation of the pressurized chamber during the impact is measured, and nitrogen gas behavior is monitored.
2) Time averaged emissions from CN and C_2 molecules are recorded by a multichannel spectrometer. And CN rotation temperature is evaluated using a softoware.
3) Time variation of the emission spectrum is measured by a streak camera. The emission from the plume continues for about 20 us.
4) Production of amino acids is examined by using the dabsyle reaction and the HPLC method, resulting in the detection of considerable amount of glycine, alanine and proline. Detection of amino acids are carefully repeated, and the effect of the contamination is avoided.

Acknowledgements

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