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Production of Carbon Clusters by Impact Reaction of Gas Gun (Model Experiment of Surface Reaction on Titan)

ガス銃衝突による炭素クラスターの合成（タイタン表面反応のモデル実験）

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In order to investigate production process of carbon clusters by asteroid impacts in space, simulation experiment is carried out using a 2-stage light gas gun. Especially, impact reactions on Titan's surface with rich hydrocarbons are considered. A small polymer bullet (a metal bullet) with about 6 km/s is injected into a pressurized target chamber to collide with an metal target (or a hexane + metal target) under 1 atm of nitrogen gas. As a result, production of many kinds of nano-scale carbon clusters such as metal-capsulated carbon particles, nanotubes and balloon-like carbons is confirmed.

1. Introduction

A huge number of carbon atoms have been produced and stored in space. They react in space by collisions, irradiation of UV light and X ray, and make many kinds of carbon clusters and hydrocarbons. We hope to know what kinds of carbon molecules and carbon compounds are stored in space. Cassini/ Huygens explorer investigated the surface of Titan, and sent clear IR images of huge methane seas on the surface. [1] Here, we suggest that the impacts of many asteroids onto the Titan's surface caused large-scale explosions in the nitrogen atmosphere, and many types of carbon clusters, hydrocarbon molecules and amino acids have been produced. [2-4] Many of the products fell on the surface and remain under low-temperature and UV-shielded conditions. However, some of the products would have been dispersed into space by the impact force. Therefore, we expect that many types of carbon clusters produced by the impacts are stored on Titan's surface. In order to prove the possibility of this hypothesis, a model experiment was carried out by using a 2-stage light-gas gun. [5] A projectile with a velocity of about 6 km/s collides with a target in a nitrogen environment causing an impact reaction in gas phase. The produced samples are carefully analyzed by a TEM *etc.*

2. Experimental

The experiment is carried out using a 2-stage light-gas gun facilitated at ISAS/JAXA. 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 km/s under a vacuum, and the bullet collides with a metal target (or a hexane + metal target) in a pressurized chamber, where 1 atm of nitrogen gas is filled. Schematic of the experimental setup (the pressurized chamber) is shown in Fig. 2. At the end of the big target chamber of the gas gun, a pressurized impact chamber is placed, which has 255 mm in diameter and 250 mm long. To collect produced small amount of samples, 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 projectile penetrates the aperture of the chamber with a thin aluminum film, and hits metal target 76 mm in diameter and 30 mm thick under 1 atm of nitrogen gas The target can be cooled down to T_t ~ - 50 degree C by thermal conduction. On the metal target, thin hexane layer about 2 mm thick can be set with an aluminum-film. After the impact, a metal shutter immediately closes the aperture to protect impurity inflow from the gun region.

3. Experimental Results and Discussion

The impact reactions are recorded by a high-speed camera (Shimadzu Co., HPV-1), which is set at a side-wall port of the target chamber. Figure 3 shows typical image of the impact emission just after the impact. After the impact the strong emission continues for about 30 μ s. From this emission, N_2-swan bands can be measured and the gas temperature is estimated to about 5000 K, which was reported by Kurosawa *et al*. [6] The impact immediately heats up the target surface to 5000 C, and

ablation of the target takes place under the low temperature. The ablated molecules react each other in the hot gas plume and they make many kinds of carbon clusters during the cooling process. After the impact, the pressurized chamber is opened and produced soot is carefully collected. By a TEM (JEOL Co., JEM-3000F, 300kV), images of produced samples are obtained. Carbon-atom and iron-atom mappings are obtained by the EELS method.

Figures 3 and 4shows produced iron-encapsulated carbon particles and balloon-like carbons, where polycarbonate bullet hits the iron target under 20 C. They are often observed.

4. Summary

Nano-scale carbon clusters such as iron encapsulated carbon particle, balloon-like carbon particles are produced by the impact reaction of a polycarbonate bullet (a metal bullet) onto an iron target (a Hexane + iron target) under 1 atm of nitrogen gas. The production process would depend on the projectile materials, target materials and target temperature. It is expected from the experiment that many kinds of carbon clusters and hydrocarbons have been produced and stored on the Titan's surface.

Acknowledgments

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References

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Fig. 1 Photograph of target chamber of the gas gun.

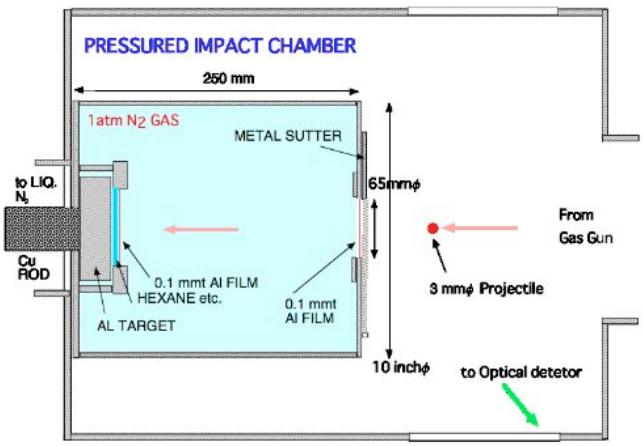

Fig.2 Schematic of the impact chamber.

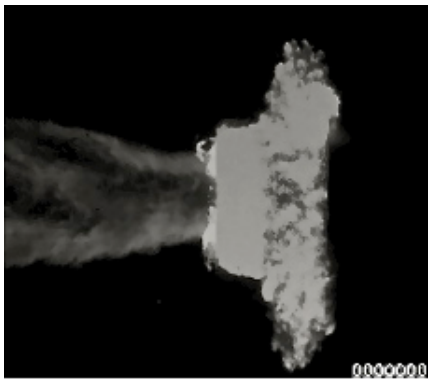

Fig.3 Photo of an impact image by a high-speed camera.

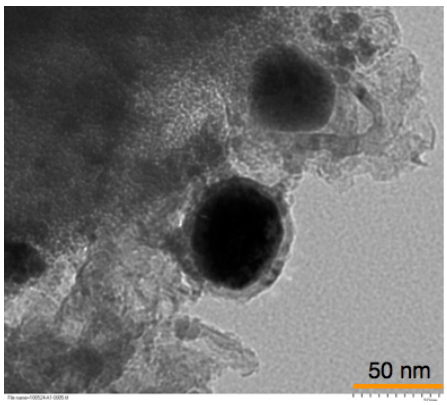

Fig. 4 TEM image of produced iron capsules.

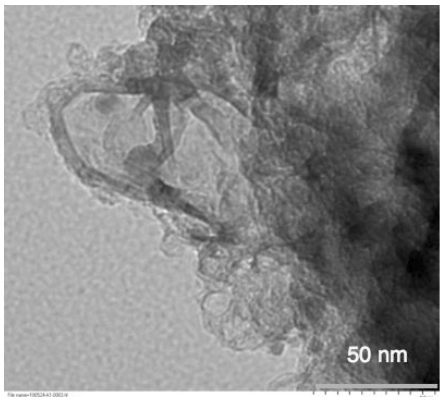

Fig. 5 TEM image of produced balloon-like carbons.