Space environment and evolution of an asteroid revealed from comprehensive analysis of a few micro-grain particles returned by Hayabusa

Eizo Nakamura[1], Akio Makishima[1], Takuya Moriguti[1], Katsura Kobayashi[1], Ryoji Tanaka[1], Tak Kunihiro[1], Tatsuki Tsujimori[1], Chie Sakaguchi[1], Hiroshi Kitagawa[1], Tsutomu Ota[1], Yusuke Yachi[1], Toru Yada[2], Masanao Abe[2], Akio Fujimura[2], Munetaka Ueno[2], Toshifumi Mukai[2], Makoto Yoshikawa[2], and Jun'ichiro Kawaguchi[2]

[1]The Pheasant Memorial Laboratory for Geochemistry & Cosmochemistry, Institute for Study of the Earth's Interior, Okayama University, Misasa, Tottori 682-0193, Japan
[2]Japan Aerospace Exploration Agency, Yoshinodai 3-1-1, Chuo, Sagamihara, Kanagawa 252-5210, Japan

Solar bodies have evolved from dust to planets with interactions between solids, and asteroids are considered intermediate products of this evolution. Asteroids were not melted and retain their primitive morphology and geochemistry, thus allowing us to investigate interactions between solids and the solar nebula. Meteorites are regarded as fragments of asteroids that fall to Earth's surface. However, information regarding the outer surface of asteroids is presumably destroyed during atmospheric entry, resulting in our inability to study the solar space-exposed exteriors of planetary bodies other than the moon sampled by the Apollo missions.

To understand solar system evolution through direct sampling of an asteroid, the Japan Aerospace Exploration Agency (JAXA) conducted the Hayabusa mission. The original plan of the mission was to collect rocks from Itokawa's surface by an impact sampling method; however, at the time of the touchdown, no projectile was fired, resulting in only minimal sample recovery. The sample capsule was returned to Earth on June 13, 2010, and opened at a JAXA curation facility. In this talk, we report an initial analysis of five lithic grains collected from a canister delivered by the spacecraft.

The lithic grains with diameters near 50 µm were comprehensively examined for surface texture and geochemistry. Oxygen isotope compositions indicate that the grains are extraterrestrial and fragments of asteroid Itokawa. Also considering the major-element compositions of the grains, it appears that Itokawa's surface is dominantly of ordinary-chondrite composition. A relatively high temperature (860 ˚C) estimated from the chemical compositions of minerals in the grains requires equilibration of the minerals in an asteroid significantly larger than the modern Itokawa. This observation implies that the genesis of Itokawa is related to a destructive process involving a larger body.

Because the grains were sampled from very near the surface of the asteroid, grain surfaces retain textures reflecting the space environment influencing the physical nature of the asteroid exterior. The surfaces are dominated by fractures, and the fracture planes contain sub-µm-sized craters and a large number of sub-µm- to several-µm-sized adhered particles, some of them glasses. The size distribution and chemical compositions of randomly sampled adhered objects, and the occurrences of sub-µm sized craters, suggest formation by hypervelocity collisions of micrometeorites down to nm-scale. Because of the low escape velocity on Itokawa and on other similar bodies, it is likely that such asteroids are major sources of interplanetary dust particles.

Although the often "potato-shaped" asteroids appear to float peacefully in space, their shapes and sizes and surface features can reflect hostile collision-related processes, at scales of 10^{-9} to 10^{4} m spatial scales and time-scales of up to 10^{9} years. Further surface observations on grains returned by Hayabusa will add statistical significance to the insights regarding solid-to-solid interactions fundamental to our understanding of asteroid accretion and, more broadly, the formation and evolution of interplanetary objects in space environment.