PRELIMINARY EXAMINATION OF PARTICLES RECOVERED FROM THE SURFACE OF THE ASTEROID ITOKAWA BY THE HAYABUSA MISSION.

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Introduction: The Hayabusa spacecraft arrived at S-type Asteroid 25143 Itokawa in November 2006, and reveal astounding features of the small asteroid (535 × 294 × 209 m) [1]. Near-infrared spectral shape indicates that the surface of this body has an olivine-rich mineral assemblage potentially similar to that of LL5 or LL6 chondrites with different degrees of space weathering [2]. Based on the surface morphological features observed in high-resolution images of Itokawa's surface, two major types of boulders were distinguished: rounded and angular boulders [3]. Rounded boulders seem to be breccias, while angular boulders seem to have severe impact origin.

Although the sample collection did not be made by normal operations, it was considered that some amount of samples, probably small particles of regolith, was collected from MUSES-C regio on the Itokawa's surface. The sample capsule was successfully recovered on the earth on June 13, 2010, and was opened at curation facility of JAXA (Japan Aerospace Exploration Agency), Sagamihara, Japan. A large number of small particles were found in the sample container. Preliminary analysis with SEM/EDX at the curation facility showed that at least more than 1500 grains were identified as rocky particles, and most of them were judged to be of extraterrestrial origin, and definitely from Asteroid Itokawa [4]. Minerals (olivine, low-Ca pyroxene, high-Ca pyroxene, plagioclase, Fe sulfide, Fe-Ni metal, chromite, Ca phosphate), roughly estimated mode the minerals and rough measurement of the chemical compositions of the silicates show that these particles are roughly similar to LL chondrites [5]. Although their size are mostly less than 10 μm, some larger particles of about 100 μm or larger were also identified.

A part of the sample (probably several tens particles) will be selected by Hayabusa sample curation team and examined preliminary in Japan within one year after the sample recovery in prior to detailed analysis phase. Hayabusa Asteroidal Sample Preliminary Examination Team (HASPET) has been preparing for the preliminary examination with close cooperation with the curation team.

Examination Goals: The basic goals of the preliminary examination are as follows.

(1) Characterization of the surface material of Itokawa, such as classification, formation age, and formation process and conditions. Especially, it is fundamental whether the Itokawa sample is really a material corresponds to an LL chondrite as indicated by the IR study [2] or other material, such as a primitive achondrite [6]. So far, there is no direct evidence between the spectral types of asteroids and corresponding meteorites although there has been accumulation of large numbers of observation of asteroids and analysis of meteorites.

(2) Understanding processes on a preexisting parent body of Itokawa and accretion into Itokawa. Itokawa is considered to be formed by an early collisional breakup of a preexisting parent asteroid followed by a re-agglomeration into a rubble-pile object [1]. Examination of brecciation, degrees of impact, etc. will give new insights on the asteroid formation processes.

(3) Understanding interaction with space environment, such as space weathering, and isotopic compositions of oxygen and noble gases of the solar wind. Nanoparticles of metallic iron, which were found as space weathering products in Apollo lunar samples, will be detected on the surfaces of Itokawa particles. The isotopic compositions of oxygen and noble gases of the solar wind implanted onto the Itokawa's surfaces will be also measured. It should be noted that the returned samples are not suffered from earth's atmospheric contaminations, especially oxygen and noble gases.

(4) Finding foreign substances fallen onto the surface. Fragments of primitive materials, such as carbonaceous and organic materials, and differentiated mate-

rials, such as granitic materials and halite, are usually included in ordinary chondrites. Especially, if organic materials are included in the Itokawa samples, the samples, which are not suffered from biotic contamination, will be analyzed. Particles of silica minerals and K-bearing halite are found in the sample catcher [5] although their definite origin is unknown at this moment.

Preliminary Examination Policies: Preliminary examination plan has been discussed since Hayabusa mission started. In order to examine a limited number of small particles, preliminary examination plans for different sample conditions have been prepared after the sampling on Itokawa. The basic policies of the preliminary examination are as follows.

(1) As the sample is not suffered from terrestrial contamination, we make maximum consideration to avoid terrestrial contamination, and obtain data that cannot be obtained from meteorites, such as space weathering, solar wind isotopic compositions, and organic materials.

(2) We have to obtain as much data as possible effectively even from a small amount of samples by systematic analyses from non-destructive to destructive ways with minimum contamination in upstream analysis.

Preliminary Examination Plan and Sub-teams: We have seven sub-teams; (1) mineralogy and petrology by XRD, XRF, SEM, EPMA and TEM, (2) three-dimensional structures by tomography, (3) elemental compositions by nuclear analysis, (4) isotopic and minor elemental compositions by SIMS, (5) noble gas analysis, (6) carbonaceous matter by micro-spectroscopic approach, and (7) organic compound by CG and TOF-SIMS.

We determined quasi-final flow chart for the preliminary examination after the observation of particles in the curation facility. The flow chart is mainly divided into two parts: one is a mainstream and the other is individual analysis flows for specific purposes.

In the mainstream, each particle will be examined first by non-destructive analyses using synchrotron radiation at Spring-8 and KEK, Japan. Mineral compositions, elemental compositions and three-dimensional structures were determined by XRD, XRF and micro-tomography, respectively. Based on the non-destructive information, each particle will be cut with an ultra-microtome. Ultra-thin sections will be analyzed by TEM, and a potted butt will be analyzed by SEM, EPMA and SIMS. If carbon is present in the cross section, organic material analyses will be made with X-PEEM/XANES and TOF-SIMS.

Five individual analysis flows are scheduled for different particles form those used in the mainstream. (i) Carbonaceous matter on the particle surface will be examined by micro-Raman and micro-IR/fluorescence. Organic materials will be extracted form the particle and analyzed. After the extraction, the residual solid particle will move to to the mainstream. (ii) Noble gas analysis will be made using mass spectrometry without exposing particles into the air. (iii) If a large particle (>~1 μg) is present, the elemental composition will be determined by INAA. If radioactivity is lower than the threshold, the particle will move to to the mainstream. (iv) The evidence of space weathering will be examined. The samples for TEM analysis will be prepared by an ultra-microtome without exposing the particles into the air and without using water. Potted butts will move to to SEM and EPMA analysis in the mainstream. (v) If a large single particle of metallic iron or iron sulfide is present, isotopic compositions of oxygen of the solar wind implanted onto the surface will be measured by SIMS. This sample will be also going to the mainstream by skipping the non-destructive analysis.

The sequential examination will start from January 2011. Result of each analysis will be presented by CoI's of the sub-team in this conference.

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