Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

U02-01 Room:201A Time:May 21 09:00-09:15

Comparative analysis of surfaces of Itokawa regolith, LL chondrite and experimentally shocked olivine fragments

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Hayabusa spacecraft recovered regolith particles from S-type Asteroid Itokawa, which is a rubble pile asteroid [1]. In preliminary examinations of the particles [2-7], it was revealed that most of the particles correspond to the thermally metamorphosed LL5 or LL6 chondrites [2-4]. Three-dimensional shape distribution of Itokawa particles suggests that the particles are consistent with fragments mechanically crushed by impacts [4]. On the surface of the particles, evidence of space weathering [6,7] and structures similar to micro-or nanocraters [8] were also found.

Thus, surface activities of the asteroid and their formation histories can be revealed from analysis of recovered regolith particles. However, systematic observation for microstructure on the surface especially in connection with comparison with the internal structures has not been made. Observation for mechanical fragments in LL chondrites, which have not been suffered space weathering, and recovered fragments of shock experiments is also important. Therefore, in this study, observation of these particle surfaces was made using a field emission-scanning electron microscope (FE-SEM). FE-SEM images were compared with 3D structures obtained by X-ray micro-tomography [9].

Itokawa particles (four particles from room-A, four particles from room-B), three fragments of Tuxtuac meteorite (LL5), three Ensisheim meteorite (LL6) were used in this study. FE-SEM (JSM-7001F) observation was performed with an energy-dispersive X-ray spectroscopic (EDS) analysis at Osaka University. In order to evaluate shock-induced microstructures of Itokawa particles, manually crushed olivine and experimentally shocked olivine fragments were also observed. Shock experiments were performed using Gekko XIIat Institute of Laser Engineering, Osaka University. The maximum pressure of shock experiments was approximately 38 GPa. X-ray micro-tomography for Itokawa regolith and LL chondrites was made at beamline BL47XU of Spring-8, Hyogo, Japan [9].

As a result of FE-SEM observation, Itokawa regolith surfaces can be divided into two types. First type (Type 1) mainly consists of cleaved faces and another type (Type 2) consists of grain boundaries. Similar cleavage surfaces like Type1were also observed on crushed olivine fragments, LL5 and LL6 fragments. Type 1 surfaces may correspond to broken surfaces of large grains of a mineral (olivine, pyroxene and plagioclase) with cleavages. Surfaces like Type 2 structures were also observed in LL chondrites. The both type surfaces of Itokawa regolith can be subdivided into fresh and matured surfaces. Fresh surfaces have sharp edges and steps. On the other hands, matured surfaces have rounded edges and eroded surfaces, which were not observed in olivine particles and LL chondrites. Objects similar to melt drops and melt splashes were usually observed on the matured surfaces. They might be formed by the hypervelocity impacts of meteoroids. The matured surfaces were probably formed by space weathering as mechanical abrasion by grain motion [4] and/or sputtering of solar wind and cosmic ray radiation [6] on surfaces of Itokawa and/or its parent body. Recovered shocked olivine fragments have many cracks and cleavage in various directions due to plastic deformation, which feature is not observed on Itokawa regolith and LL chondrites. The results suggest that particles experienced such a high pressure might escaped from asteroidal surfaces.

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Keywords: Itokawa, regolith, LLchoondrite

Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

U02-02 Room:201A Time:May 21 09:15-09:35

Shock state of the Itokawa samples

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Introduction: One of the fundamental aspects of any astro-material is its shock history [1]. The Hayabusa Preliminary Examination Team (HASPET) made shock stage determination of the Itokawa samples a primary goal [2]. The shock state of ordinary chondrite materials is generally determined by simple optical petrographic observation of standard thin sections, which we also did here. We made an additional estimation of the sample shock state by electron back-scattered diffraction (EBSD). We are also investigating the crystallinity of Itokawa olivine by synchrotron X-ray diffraction (SXRD).

Results: We made EBSD maps of 6 equilibrated (LL5/6) Itokawa. The EBSD maps revealed that olivine crystallinity varies considerably within the space of a few micrometers, and likewise albite, troilite and chromite. Albite was sometimes better crystalline than adjacent olivine, counter to our expectations. However, local variations in degree of crystallinity is a hallmark of shock metamorphism [1,4]. In order to determine the relative shock degree of the Itokawa grains we duplicated the EBSD analysis using grains from the Kilabo LL6 (shock stage S3) and Alfianello L6 (S5) ordinary chondrites. We used completely equilibrated type 6 chondrites in order to avoid potential complications from variable mineral compositions. By visually comparing the overall crystallinity of samples from EBSD and Band Slope maps we estimated that Itokawa samples should be assigned to be intermediate between Kilabo and Alfianello, therefore shock stage S4 by EBSD. We also determined the shock state of the Itokawa samples in the conventional manner under crossed polars in a standard petrographic microscope. Despite the irregular and non-standard specimen thickness this was surprisingly easy to do. We examined 29 separate grains. Practically all crystallites in the Itokawa grains exhibited minor to pronounced undulatory extinction. Some grains displayed distinct mosaicism. We saw no instances of shock veins in the equilibrated (LL5-6) grains, but there were amorphous regions in the unequilibrated LL4 grains. We observed no obvious parting or planar deformation features. Given the natural variability of shock effects [1] , these petrographic observations indicate shock stage S2, which is considerably lower than that suggested by the EBSD images (S4). To verify that shock levels were lower than S4 we have begun collecting SXRD data on larger Itokawa olivine grains. Grain RA-QD02-0049-2 consists almost entirely of olivine, and its diffraction pattern was very sharp, indicating insignificant shock metamorphism for this particular grain.

Conclusions: Shock effects can be effectively studied from even the tiny Itokawa grains, and by multiple techniques. It would be interesting to examine IDPs and lunar regolith grains in the same manner. However, EBSD and standard petrographic techniques are not equally sensitive to very fine-scale shock effects. EBSD appears to have greater potential to elucidate shock effects at the finest scale, but if EBSD data only are used to assign a shock stage these results may not be directly comparable to those obtained by standard petrographic techniques.

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Keywords: Hayabusa, Asteroid, Shock State

Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

U02-03 Room:201A Time:May 21 09:35-09:50

A micro-spectroscopic research for the particles returned by the HAYABUSA mission

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Introduction: We have reported on micro-spectroscopic analyses of the particles returned by the HAYABUSA mission, in search of insoluble organic matter (IOM) [1-2]. It suggests to what extent thermal metamorphism has proceeded [3-7]. Five particles from the room A (RA-QD02-0017, 0033, 0044, 0049, and 0064) were analyzed by non-destructive methods; micro-Raman and IR techniques. The major Raman bands and IR absorptions can be assigned to olivine, and it seems the major mineral. Two particles from the room B (RB-QD04-0025 and RB-QD04-0049) were also analyzed in the same manner. The Raman spectra of RB-QD04-0049 showed that olivine is its major mineral, and the Raman bands of RB-QD04-0025 can be assigned to pyroxene and merrilite. However, the spectra lack in Raman bands or IR absorptions relating to carbonaceous matter. Although the seven particles may contain trace amount of low molecular weight organic compounds, there is no evidence for chondritic IOM [2]. In addition to the particles, we examined two particles by micro-Raman and IR techniques. And four particles were investigated by photoelectron emission microscopy (PEEM).

Methods: Two particles (RA-QD02-0008 and RB-QD04-0001) are analyzed by micro-Raman and IR in the same method using the newly designed sample holder made from diamond plates without using organic resin [1]. PEEM analyses were performed at the end-station of BL17SU in SPring-8. Four particles (RA-QD02-0010, RA-QD02-0031, RA-QD02-0068, and RB-QD04-0025) were analyzed using potted butt.

Results: RA-QD02-0008 and RB-QD04-0001 showed relatively strong fluorescence background at the Raman spectra. The IR spectrum of the particle RA-QD02-0008 is characterized by broad O-H stretching, however C-H stretching was not observed, unlike chondritic IOM. A PEEM image of the particle RA-QD02-0068 showed one carbon-rich phase in the particle.

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Keywords: Hayabusa, Micro-spectroscopic analyses, Carbonaceous matter

U02-04 Room:201A Time:May 21 09:50-10:05

STEM observation of space weathering products on the Itokawa dust particles and importance of N2 purge environment

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Surfaces of airless bodies exposed to interplanetary space gradually have their structures, optical properties, chemical compositions, and mineralogy changed by solar wind implantation and sputtering, irradiation by galactic and solar cosmic rays, and micrometeorite bombardment. These alteration processes and the resultant optical changes are known as space weathering [1, 2, 3]. Our knowledge of space weathering has depended almost entirely on studies of the surface materials returned from the Moon and regolith breccia meteorites [1, 4, 5, 6]. Lunar soil studies show that space weathering darkens the albedo of lunar soil and regolith, reddens the slopes of their reflectance spectra, and attenuates the characteristic absorption bands of their reflectance spectra [1, 2, 3]. These changes are caused by vapor deposition of small (less than 40 nm) metallic Fe nanoparticles within the grain rims of lunar soils and agglutinates [5, 6, 7].

Structure of nanoparticle-bearing rims by the initial analysis of the Itokawa dust particles are as follows. Sulfur-bearing Fe-rich nanoparticles exist in a thin (5-15 nm) surface layer (zone I) on olivine, low-Ca pyroxene, and plagioclase, suggestive of vapor deposition. Sulfur-free npFe exist deeper inside (less than 60 nm) ferromagnesian silicates (zone II). Their texture suggests formation by amorphization and in-situ reduction of Fe2+ in ferromagnesian silicates [8]. On the other hand, nanophase metallic iron in the lunar samples is embedded in amorphous silicate [5, 6, 7]. These textural differences indicate that the major formation mechanisms of the metallic nanophase iron are different between the Itokawa and the lunar samples.

Eleven of them were embedded in epoxy resin and ultramicrotomed into about 100 nm-thick ultrathin sections. Four of them were preserved in N2 purge environment from the curation facility at ISAS/JAXA through ultramicrotomy at Ibaraki University to STEM observation at Hitachi high-technologies Co. Six samples were enclosed in thin (a few micrometer thick) epoxy resin at the curation facility to avoid long-haul exposure to the earth's atmosphere during experiments at Spring-8 and KEK-PF. Although these six samples ultramicrotomed in the earth's atmosphere, dehydrated ethylene glycol was used as trough liquid instead of distilled water to avoid unnecessary contact with water. Total exposure time to the earth's atmosphere was less than a few hours for these samples. One sample was kept in a desiccator for about one month at Osaka University, which means that it was kept in earth's atmosphere for a month. To evaluate the effect of long exposure to the earth's atmosphere, ultrathin sections were prepared for this sample by using the same procedures of the above six samples. All the samples were investigated using a spherical aberration corrected scanning transmission electron microscope to investigate space weathering products on the samples.

STEM observation of these particles revealed that some nanoparticle-bearing rims are vesiculated. Different from vesicular rims on the surface of lunar samples [5, 6], vesiculation occurred at the boundary between zone I and zone II or within zone II. We found that two samples without nanoparticle-bearing rims by have quite thin (2-3 nm) surface layers with elements that are not included in the substrate minerals, suggestive of vapor deposition from the surrounding minerals. We think that the quite thin layers are the immediate-early product of space weathering.

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Keywords: Itokawa, Space weathering, N2 purge environment

Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

U02-05 Room:201A Time:May 21 10:05-10:20

Preliminary examination of Hayabusa asteroidal samples: oxygen isotope and trace elements analyses

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Introduction: Oxygen isotopic compositions of asteroidal materials returned from Itokawa by the Hayabusa mission are all depleted in O-16 relative to terrestrial materials and indicate that Itokawa, an S-type asteroid, is one of the source of the LL or L group to equilibrated ordinary chondrites (Yurimoto et al., 2011). As the second round measurements, we measured, using secondary ion mass spectrometry, oxygen isotopic compositions and trace elements of individual minerals in 5 grains including poorly equilibrated particles from petrologic observations returned from Itokawa by the Hayabusa mission.

Experiments: Each grain was mounted at the center of an epoxy disk and the surface was polished under the processes established for the preliminary examination. The samples were gold-coated to a thickness of 60 nm.

Oxygen isotope compositions and trace element have been investigated by the Hokudai isotope microscope system (Cameca ims-1270 and 6f SIMS). The detail analytical conditions of oxygen isotope analyses are shown in Yurimoto et al. (2011). Trace elements analyses were performed by 6f SIMS in Hokudai. A 23keV O- primary ions is focused to ~15micron on the sample surface and secondary ions were collected with EM. The detail analytical conditions were shown in Yurimoto et al. (1989).

Results and Discussion: All oxygen isotopic compositions of the minerals from Itokawa plot on the upper side of terrestrial materials on an oxygen three-isotope diagram and are distributed parallel to the terrestrial mass fractionation line. This result is consistent with those of L or LL chondrites. Even if some particles show the fractionated delta values (olivine) relative to those of other particles, the isotopic relationship among olivine, orthopyroxene and plagioclase shows that the oxygen isotopes fractionated under equilibrium between coexisting phases. On the basis of the small variation of D17OSMOW, the poorly equilibrated grains may have caused by late thermal process (e.g., shock melting) from the equilibrated grains made by thermal metamorphism like other Itokawa equilibrated grains. We measured trace elements of mesostasis parts in less equilibrium particles. Incompatible trace elements are enriched in the mesostasis. REE patterns are less fractionated among LREEs and HREEs.

Acknowledgements: We thank Hayabusa sample curation team and Hayabusa project team for close cooperation.

Keywords: Hayabusa, asteroid, isotope, oxygen, trace element

Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

U02-06 Room:201A Time:May 21 10:45-11:00

Outline of the next asteroid sample return mission - Hayaubsa-2

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From 2011, Hayabusa follow-on mission, Hayabusa-2, has started. It is an asteroid sample return mission like Hayabusa, but the type of the target asteroid is C-type, which is different from the target of Hayabusa, Itokawa (S-type). It is considered that C-type asteroid contains more organic or hydrated minerals, so we can investigate the origin of water and organic matter of the life on the earth as well as the origin of the planets. The scale of the spacecraft is similar to Hayabusa, but many parts will be modified so that we will not have the troubles that we experienced in Hayabusa. Also the spacecraft has new equipment, which is called impactor. The impactor will make an artificial crater on the surface of the asteroid, and we will try to get the sample inside the crater. Then we can get much fresh material. The planned launch year is 2014 (2015 as backup), arriving at the target asteroid 1999 JU3 in 2018, and coming back to the earth 2020.

Keywords: Planetary exploration, Spacecraft, Asteroid, Sample Return, Hayabusa

Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

U02-07 Room:201A Time:May 21 11:00-11:15

Hayabusa-2, scientific objective and instruments

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”Hayabusa2” is a successor asteroid sample-return mission of ”Hayabusa” (MUSES-C), which proved several new technologies and returned to Earth in June 2010. While establishing a new navigation method using ion engines, Hayabusa succeeded in bringing back samples from the S-type asteroid ”Itokawa”. A C-type asteroid ”1999 JU3” is a mission target of Hayabusa2 to solve the material changes accompanying evolution from primitive solar nebula to present asteroid, and to elucidate the formation and dynamical history of planetesimal and present asteroid. A C-type asteroid is a more primordial body than an S-type asteroid, and is considered to contain more organic or hydrated minerals. Minerals and seawater which form the Earth as well as materials for life are believed to be strongly connected in the primitive solar nebula in the early solar system, thus we expect to clarify the origin of life by analyzing samples acquired from a primordial celestial body such as a C-type asteroid to study organic matter and water in the solar system and how they coexist while affecting each other. The configuration of Hayabusa2 is basically the same as that of Hayabusa, but we will modify some parts by introducing novel technologies that evolved after the Hayabusa era. For example, a new function, ”collision device”, is considered to be onboard to create a crater artificially. An artificial crater that can be created by the device is expected to be a small one with a few meters in diameter, but still, by acquiring samples from the surface that is exposed by a collision, we can get fresh samples that are less weathered by the space environment or heat. Onboard scientific instruments are a near infrared spectrometer and mid infrared camera. Optical camera and laser altimeter which are carried for navigation guidance are also used for scientific objective. Small lander and/or rover are also planned to be carried. Hayabusa2 is scheduled for launch in 2014 (or 2015 as a backup.) It should arrive at the C-type asteroid in mid 2018, staying around there for one and half years before leaving the asteroid at the end of 2019 and returning to Earth around the end of 2020.

Keywords: asteroid, sample return, remote sensing, exploration

Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

U02-08 Room:201A Time:May 21 11:15-11:30

Science priorities for Hayabusa-2 return samples

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Recent progresses in research of extraterrestrial materials have revealed that the most pristine materials in the solar system are an interacted mixture of minerals, ice, and organic matter. However, there have been no returned samples keeping the interactions between inorganic materials, ice and organic matter intact. In this talk, we will illustrate the importance of sample-return return missions from undifferentiated primitive asteroids and comets, which preserve pristine minerals, ice, and organic materials, and introduce the scientific priorities for Hayabusa-2 return-samples from a C-type asteroid 1999 JU3.

Keywords: Hayabusa-2, C-type asteroid, sample return

Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

U02-09 Room:201A Time:May 21 11:30-11:45

Thermal Property of Asteroid 1999JU3 by Infrared Imager TIR on Hayabusa2

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A thermal infrared (TIR) imager is a nominal remote-sensing instrument onboard Hayabusa2, to investigate physical properties of the surface of C-class Near-Earth Asteroid 1999JU3. The instrument is based on the LIR (Long-InfraRed imager) onboard Akatsuki, a Japanese Venus climate orbiter to be inserted into Venus orbit in 2015 or 2016. Science objectives and current status of the instrument are briefly reported.

Hayabusa2 is the follow-on mission after the Japanese asteroid explorer Hayabusa and primarily an NEO (Near-Earth Object) sample-return mission, but remote sensing also has much importance to characterize global nature of the target body, which is complementary to analysis of returned samples. Since the target body is a C-class asteroid, optimal set of instruments is different from that of Hayabusa: telescopic (multi-band) imagers, laser ranger, near-infrared spectrometer to identify 3 micron absorption band, and a thermal infrared imager.

The original LIR instrument on Akatsuki has been developed for mapping Venus clouds at the temperature range of 220-250K. The instrument is applicable to mid-infrared imaging to investigate thermal inertia of asteroid surface. The instrument adopts a non-cooled bolometer array as its detector. The instrument has a field of view of 16 x 12 degree, detector of 320 x 240 effective pixels, and its targetted detection temperature range of 250 to 400K. The total mass is about 3.3 kg including the detector unit, hood, and electronics.

The main scientific missions are to investigate the global and local areal distribution of the surface physical properties. Surface physical properties are determined in 10 m spatial resolution from the Home Position 20km sunward from the asteroid. Higher resolved images are taken at lower altitude during the descent operation for touchdown. Thermal properties reflect the condition of materials, i.e. porosity of regolith or rocks, or particle size of soils. It will help understand the surface sedimentation processes under microgravity. Condition of large boulders or inner wall of huge craters informs the internal condition and alteration processes of parent body or current asteroid, respectively. Yarkovsky or YORP effects will be investigated by thermal imaging. TIR will also measure the properties of the surface geologic feature, crater ejecta, surrounding moons or floating dusts if they exist.

The TIR imager will also play an imprtant role for giving an information on sampling site selection by its surface physical condition as well as for assessing the spacecraft safety operation for touchdown by thermal emission or temperature.

Keywords: asteroid, Hayabusa2, thermal property, bolometer, TIR

Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

U02-10 Room:201A Time:May 21 11:45-12:00

Scientific Objectives of Hayabusa-2 LIDAR experiment

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We introduce scientific objectives of LIDAR experiment of Hayabusa-2 mission. Members of the LIDAR science team increased October, 2011, to promote geodetic studies of asteroid and to help development of LIDAR instrument in the prospect of scientific use of the ranging data. Then we redefined the scientific objectives of LIDAR experiment as follows:

(1) To identify collisional family of 1999JU3 from albedo map taken by LIDAR in addition to in situ spectral measurements of AMICA and NIRS3

(2) To elucidate the nature and history of accretion and destruction of rubble pile body on the basis of average porosity

(3) To constrain orbital evolution of 1999JU3 from irradiation age of cosmic rays and implantation of solar wind elements.

Further, we discussed what kind of observations Hayabusa should have conducted at Itokawa to maximize achievements of chemical analyses of returned samples, and concluded that following two points should be considered for Hayabusa-2.

(4) To prove or disprove universal existence of rubble pile bodies from a comparison of Itokawa and 1999JU3 and spatial variation of porosity

(5) To explore dust environment around asteroid by detecting levitating dust and dust ejected from artificial impact

In this talk, the above objectives are explained in detail with expected spec of LIDAR instrument and possible scenario of the proposed observation.

Keywords: asteroid, planetary exploration, hayabusa

Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

U02-11 Room:201A Time:May 21 12:00-12:15

Science from Small Carry-on Impactor

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Small Carry-on Impactor (SCI) is one of the instruments carried on Hayabusa-2 space craft and it will be used for the active exploration on the surface of 1999JU3. The SCI consists of a disk impactor with the diameter of 30cm made of cupper and this disk will be deformed by an explosion to form a semi-spherical shell and be accelerated to be about 2km/s for the collision on the asteroid surface. The purpose of the SCI is to enable the sampling from the interior of the asteroid, so the sample will be recovered from the floor of the artificial crater or the surrounding area covered with the ejecta from the SCI artificial crater. Moreover, the SCI will create a new fresh surface in the artificial crater without any space weathering, then the remote sensing will be able to refer this fresh surface to recognize the space weathering on other JU3 surfaces and to also observe the subsurface structure on the crater wall.

In order to confirm the ability of these observations and the sample recover in the artificial crater, we should estimate the crater size and the excavation depth in advance. We can estimate the various crater parameters formed by the SCI impact according to the conventional crater scaling law constructed by Holsapple group when the asteroid surface is assumed to be a homogeneous incompressive material like a sand layer. We can estimate the crater size, the depth of excavated material, and the maximum rim thickness for the SCI impact on the sand layer of a JU3 size body. For example, when the 2kg cupper impactor is collided on the JU3 surface, we can calculate that the crater diameter is about 5m, the rim thickness is 1m, and the maximum excavation depth is 1.2m.

However, as you know, we have no reliable mechanical data of the JU3 surface for the feasibility check of the SCI. Thus, the most important purpose of the SCI is to clarify the surface mechanical condition of the JU3. Moreover, the tiny bodies like 1999JU3 and Itokawa have a large advantage to investigate the effect of gravity on the crater formation because on the earth it is quite difficult to study the gravity effect on the crater formation, so it should be examined by the SCI impact to refine the crater scaling law related to the gravity effect. The JU3 surface is a very good plat form for the impact experiment: it is a real asteroid and the gravity is quite small and stable which can not be achieved on the earth. Thus, we consider that the SCI impact is equal to the large scale impact experiment extrapolated from the laboratory experiment.

The SCI impact will be recorded by the detached small camera or deployable camera (DCAM) and the ejecta curtain or the impact fragments will be observed to investigate the surface mechanical structure. The artificial crater will be explored by ONC, TIR, and NIRS3 to obtain the basic parameters of the impact crater and the various information of the fresh surface and the subsurface structure. These information will be used to determine the physical properties of the subsurface material and to refine the crater scaling law for the ejecta velocity distribution and the crater diameter. The cooperation with the laboratory experiments and the numerical simulations is very important to utilize the obtained results and to conduct the realistic extrapolation of the scaling law in the large scale. Our SCI science team will do our best to succeed the SCI experiment with a motto that Small Carry-on Impactor Elucidates the Nature of Craters and Ejecta (SCIENCE).

Keywords: 1999JU3, Impact experiment, Artificial impact crater, Crater scaling law, Space weathering

Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

U02-12 Room:201A Time:May 21 13:45-14:00

Laboratory Experiments of Impact onto Chondrites and Ejecta Recovery

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Hypervelocity impacts from interplanetary space excavate craters, disrupt boulders, disturb regolith, and modify the material composition on asteroid surfaces. The fragments generated by the impacts are major sources of interplanetary solid bodies including dust particles. The ejecta eventually become the potential impactors onto small bodies. Lots of impact experiments onto rocks and analog targets of asteroids have been performed in the laboratory, however, only limited impact experiments using meteorites have been conducted. In an impact disruption experiment consisting of an aluminum projectile fired at a velocity of 4.45 km/s to a target of Murchison CM2 chondrite meteorite, it was shown that Murchison disruption significantly over-produced fragments of hundreds micron in size compared to anhydrous meteorite targets (Flynn et al. 2009).

Accelerating a projectile by laser ablation is suitable for conducting impact experiments onto meteorites which are limited in amount; because it can aim small projectile at the target with better accuracy than a gas-gun in general and thus requires less amount of target material. Therefore, we performed a series of hypervelocity impact experiments, in that, the target materials were an LL5 chondrite, Allende and Murchison meteorites. Aluminum spheres of 80-242 micron in diameter were accelerated by laser ablation using a GEKKO XII-HIPER laser at the Institute of Laser Engineering of Osaka University (Kadono et al. 2010). The impact velocity ranged from 10.7 to 43.9 km/s. We collected the ejecta by aerogel blocks deployed near the targets. Deep craters were formed on Murchison meteorite targets while very shallow and irregular-shaped depletions were formed on LL5 chondrite targets regardless of the impact velocity. We will also present the preliminary results of the ejecta size distribution.

Keywords: impact, asteroid, ejecta, dust, crater

Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

U02-13 Room:201A Time:May 21 14:00-14:20

MarcoPolo-R: Asteroid Sample Return Mission

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MarcoPolo-R is a sample return mission to a primitive Near-Earth Asteroid (NEA) selected for an assessment study at ESA in the framework of ESA Cosmic Vision 2 program. The assessment study started at ESA on May 2011 and will continue until the middle of 2013. MarcoPolo-R is a European-led mission with a proposed NASA contribution. MarcoPolo-R will rendezvous with a primitive NEA, scientifically characterize it at multiple scales, and return a unique sample to Earth unaltered by the atmospheric entry process or terrestrial weathering. This project is based on the previous Marco Polo mission study, which was selected for the Assessment Phase of the first round of Cosmic Vision. Its scientific rationale was highly ranked by ESA committees, and it was not selected to proceed to the next step because the estimated cost was higher than the allotted amount for an M-class mission. The aim of the new Assessment Study is to reduce the cost of the mission while maintaining its high science level, on the basis of advanced studies and technologies, optimization of the mission, and consolidation of the collaboration with other partners.

The baseline target is a binary asteroid (175706) 1996 FG3, which offers a very efficient operational and technical mission profile. A binary target also provides enhanced science return. The choice of this target will allow new investigations to be performed more easily than at a single object, and also enables investigations of the fascinating geology and geophysics of asteroids that are impossible at a single object. Several launch windows have been identified in the time-span 2020-2024. The baseline mission scenario of MarcoPolo-R to 1996 FG3 is as follows: A single primary spacecraft, carrying the Earth re-entry capsule and sample acquisition and transfer system, will be launched by a Soyuz-Fregat rocket from Kourou.

The scientific payload includes state-of-the-art instruments, e.g. a camera system for high resolution imaging from orbit and on the surface, spectrometers covering visible, near-infrared and mid-infrared wavelengths, a neutral-particle analyser, a radio science experiment and optional laser altimeter. If resources are available, an optional Lander will be added to perform in-situ characterization close to the sampling site, and internal structure investigations.

MarcoPolo-R will return bulk samples from an organic-rich binary asteroid to Earth for laboratory analyses, allowing us to:
* explore the origin of planetary materials and initial stages of habitable planet formation;
* identify and characterize the organics and volatiles in a primitive asteroid;
* understand the unique geophysics, dynamics and evolution of a binary NEA.

In addition to addressing the exciting science goals, the MarcoPolo-R mission also involves technologies for which technical development programmes are well under way. It is the ideal platform to (i) demonstrate innovative capabilities such as: accurate planetary navigation and landing, sample return operational chain; (ii) prepare the next generation of curation facilities for extra-terrestrial sample storage and analysis; (iii) develop high-speed re-entry capsule; (iv) pave the way as a pathfinder mission for future sample returns from bodies with high surface gravity.

Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

U02-14 Room:201A Time:May 21 14:20-14:40

HUMAN MISSIONS TO NEAR-EARTH ASTEROIDS: AN UPDATE ON NASA'S CURRENT STATUS AND PROPOSED ACTIVITIES

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Introduction: Over the past several years, much attention has been focused on the human exploration of near-Earth asteroids (NEAs). Two independent NASA studies examined the feasibility of sending piloted missions to NEAs, and in 2009, the Augustine Commission identified NEAs as high profile destinations for human exploration missions beyond the Earth-Moon system as part of the Flexible Path. More recently the current U.S. presidential administration directed NASA to include NEAs as destinations for future human exploration with the goal of sending astronauts to a NEA in the mid to late 2020s. This directive became part of the official National Space Policy of the United States of America as of June 28, 2010.

Dynamical Assessment: The current near-term NASA human spaceflight capability is in the process of being defined while the Multi-Purpose Crew Vehicle (MPCV) and Space Launch System (SLS) are still in development. Hence, those NEAs in more accessible heliocentric orbits relative to a minimal interplanetary exploration capability will be considered for the first missions. If total mission durations for the first voyages to NEAs are to be kept to less than one year, with minimal velocity changes, then NEA rendezvous missions ideally will take place within 0.1 AU of Earth (˜15 million km or 37 lunar distances).

Human Exploration Considerations: These missions would be the first human expeditions to interplanetary bodies beyond the Earth-Moon system and would prove useful for testing technologies required for human missions to Mars, Phobos and Deimos, and other Solar System destinations. Missions to NEAs would undoubtedly provide a great deal of technical and engineering data on spacecraft operations for future human space exploration while conducting detailed scientific investigations of these primitive objects. Current analyses of operational concepts suggest that stay times of 15 to 30 days may be possible at these destinations. In addition, the resulting scientific investigations would refine designs for future extraterrestrial In Situ Resource Utilization (ISRU), and assist in the development of hazard mitigation techniques for planetary defense.

Conclusions: The scientific and hazard mitigation benefits, along with the programmatic and operational benefits of a human venture beyond the Earth-Moon system, make a piloted mission to a NEA using NASA's proposed human exploration systems a compelling endeavor.