**OVERVIEWS OF PHYSICAL PROPERTIES OF RYUGU SAMPLE: IMPLICATIONS FOR VARIATION OF CONSTITUENT MATERIALS ON C-TYPE ASTEROID (162173) RYUGU.** A. Miyazaki[1], R. Kanemaru[1], T. Yada[1], M. Abe[1], A. Nakato[1], K. Yogata[1], K. Nagashima[1], K. Hatakeda[2], K. Kumagai[2], Y. Hitomi[2], H. Soejima[2], M. Nishimura[1], S. Furuya[1], M. Yoshitake[1], A. Iwamae[2], S. Tachibana[3], T. Okada[1], and T. Usui[1], [1]Inst. Space Astronaut. Sci., Japan Aerosp. Explor. Agency (JAXA), 3-1-1 Yoshinodai, Chuo, Sagamihara, Kanagawa 252-5210, Japan (miyazaki@planeta.sci.isas.jaxa.jp), [2]Marine Works Japan Ltd., 3-54-1 Oppama-Higashi, Yokosuka 237-0063 Japan, [3]UTOPS, Grad. Sch. Sci., Univ. Tokyo, 7-3-1 Hongo, Bunkyo, Tokyo 113-0033, Japan.

**Introduction:** JAXA Hayabusa2 mission collected the surface and sub-surface materials from the C-type near-Earth asteroid 162173 Ryugu, and brought back 5.4 g of samples in total to the Earth [1]. The samples collected during the first and the second touchdowns, were stored in the Chambers A and C, respectively [2]. These samples were recovered to perform the initial descriptions in the curation facility of the Extraterrestrial Sample Curation Center (ESCuC) in Sagamihara, Japan [1].

A preliminary report by Astromaterials Science Research Group (ASRG) of ISAS [1] shows that Ryugu samples are most similar to CI chondrites with optical and visible to near-infrared spectral observations [1]. Hence, Ryugu particles might be primitive material in the Solar System.

We report here the overviews of physical properties of 407 picked-up particles of Ryugu sample. All the measurements are conducted in non-destructive ways, and performed in purified nitrogen environment in the clean chambers (CC), without exposure to the Earth's atmosphere.

**Methods and samples:** The size, weight, and density of the individual Ryugu particles were studied as follows: (1) Those particles were hand-picked one by one with vacuum tweezers from the bulk sample containers to the individual sapphire dishes. The tip of the vacuum tweezers to touch the sample is made of stainless steel. (2) Images of the particle were taken using an optical microscope (Nikon SMS-1270i) with XYZ electric motor system equipped above the CC thorough a soda-lime glass window. (3) The feret diameter of the particle was measured using an imaging software (NIS-Elements). The volume of the particle was calculated based on the method adopted in Yada et al.[1] using the max- and the min- feret diameters (x, y) and the height (z) of the samples. Note that the estimated volume is subject to potential error due to the method. (4) The weight of the particle was measured by an electronic balance (Mettler-Toledo XP404s) in the CC, modified the plastic cover to metallic one in order for the contamination control. We adopted the average of five measurements as the weight of the particle. (5) The density of the particle was calculated by dividing the measured weight by the estimated volume.

**Results and discussion:** The Ryugu particles were picked up from the relatively large particles, and the majority of particles larger than ~10 mg have been picked up so far. In this section, we show the results of the analyses for relatively large particles (407 particles).

*Optical microscopy.* Most Ryugu particles show dark to grayish color. The appearance of the particles show variety of shapes (round, angular, and accumulated shapes) [3]. The surface of the particles varies from smooth (flat) to rough and there are some particles that show a glossy and/or bright surface (Fig. 1) [3,4]. Several unique particles have bright inclusions and/or transparent crystals [3,4]. These inclusions correspond to carbonates based on FTIR and MicrOmega analyses [e.g., 5-7].

These variations might be due to the differences in the formation and secondary processes (petrologic types or space weathering). It is difficult to elucidate the evolution process by optical microscopy alone.

*Weight, size, volume, and density analyses.* The samples recovered from the Chambers A and C were 3.237 ± 0.002 g and 2.025 ± 0.003 g, respectively [1]. The maximum weights of the particles in the chambers A and C are 25.8 mg (A0021) and 138.1 mg (C9000), respectively. The maximum volumes of the particles in Chambers A and C are 19.61 (A0021) and 102.58 $mm^{-3}$ (C9000), respectively. The C9000 shows 10.345 mm as the maximum feret diameter. The difference in size distribution of Ryugu particles between Chambers A and C could be due to the difference in geology of the sampling sites. However, sample sizes are not simply comparable, as they may have been affected by the sampling process and subsequent destruction in the sample container mounted inside the reentry capsule [1].

The average of the estimated bulk densities of Ryugu particles is 1.282 ± 0.231 $g/cm^3$[1]. We plotted the relationship between the density and the weight of each 407 particle (Fig. 2). The density of Ryugu particles varies widely, especially for the smaller particles (0.48 to 2.18 $g/cm^3$). Some higher densities exist that are comparable to Tagish Lake meteorites (1.660 $g/cm^3$) and other CI chondrites (2.110 $g/cm^3$) [e.g., 8]. However, these higher and lower densities are mainly found in smaller particles, so it may be reasonable to attribute them to errors in weight and volume estimation, as well as sample heterogeneity. Then we focus the densities of relatively large particles (≥10 mg). The density of these particles is 1.37 ± 0.25 g/cm$^3$, which is slightly higher than that in Yada et al. [1]. The densities of Ryugu particles of Chambers A and C show 0.95 to 2.08 g/cm$^3$ and 1.03 to 1.64g/cm$^3$, respectively. In the relatively large particles, the difference in density among particles is up to twice and the variation is large. The facts suggest that the Ryugu sample contains particles with essentially different properties.

Remote sensing investigations revealed that there are several types of boulders on the surface of Ryugu. Thermal infrared imager observations onboard Hayabusa2 found three different thermal inertia on the surface of Ryugu, ~100, ~300, and ~600 tiu [9, 10]. The densities estimated from these thermal inertia are ~1.0 to ~2.0 g/cm$^3$, which are consistent with the value of the Ryugu particles studied here. Although the thermal inertia and density do not rule out the effect of abundance of fractures in the rock, Hayabusa2 may recover many types of Ryugu materials. On the other hand, Tatsumi et al. [11] indicates that the presence of fragment of S-type asteroid. No such particles have been found yet, but further research may find them in the near future.

**Summary and implications:** C-type asteroids such as Ryugu are considered to have information on not only the origin and evolution of the Solar System but also the birth of life. The variation of Ryugu particles indicates the complexity of materials and the chemical evolution in the early Solar System. Ryugu is considered to experienced catastrophic destruction [e.g., 9], and several types of boulders exist on Ryugu. The large variation of density for relatively large Ryugu particles (≥ 10 mg) suggests that Hayabusa2 recovered the several types of particles from Ryugu. It has been known that carbonaceous chondrites do not tend to survive at the entry to Earth's atmosphere. Therefore, these Ryugu particles provide a good opportunity to elucidate them. From now on, the First Announcement of Opportunity (AO) for Hayabusa2 samples will start. Ryugu particles will be used by researchers around the world to analyze the samples in detail. Furthermore, the sample return from asteroid Bennu by OSIRIS-REx by NASA allows comparison between different objects. Return samples will give us new insights into planetary science together with meteorites.

**References:** [1] Yada T. et al. (2021) *Nat. Astron., doi: 10.1038/s41550-021-01550-6*. [2] Tachibana S. et al. (2022) *Submitted to Science*. [3] Yada T. et al. (2022) *This meeting*. [4] Nakato A. et al. (2022) *This meeting*. [5] Pilorget C. et al. (2021) *Nat. Astron., doi.: 10.1038/s41550-021-01549-z.* [6] Hatakeda K. et al. (2022) *This meeting*. [7] Yogata K. et al. (2022) *This meeting*. [8] Zolensky M. et al. (2002) *MAPS 37*, 737-761. [9] Okada T. et al. (2020) *Nature 579*, 518-522. [10] Sakatani N. et al. (2021) *Nat. Astron. 5*, 766-744. [11] Tatsumi E. et al. (2021) *Nat. Astron. 5*, 39-45.

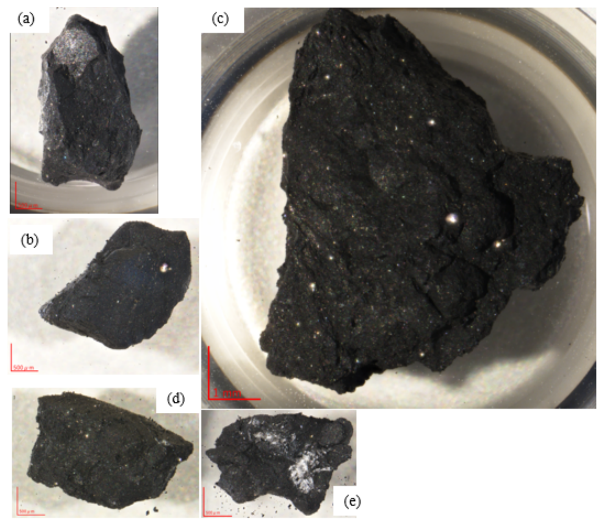


Fig. 1. Optical microscopic images of Ryugu particles of (a)A0005, (b)A0025, (c)C0001, (d)C0025 (e)C0041. It should be noted that the brightness of the light source is not adjusted, and the differences in the color of the particles are influenced by the conditions of taking pictures.

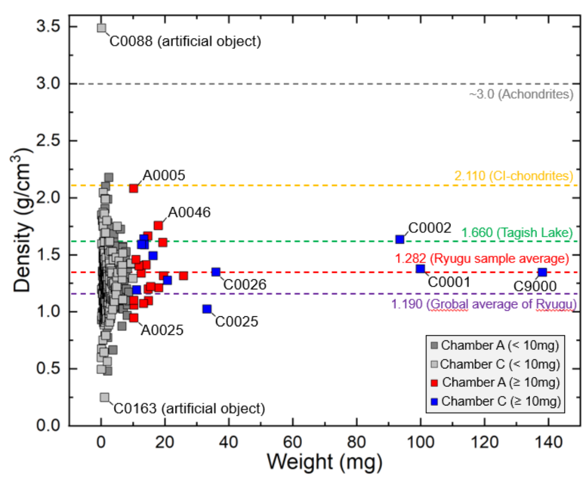


Fig. 2. Density and weight of Ryugu particles. C0088 and C0163 are considered to be the fragments of artificial objects found in the sample catcher.