SUB-MILLIMETER-SIZED RYUGU PARTICLES FOUND OUTSIDE THE HAYABUSA2 SAMPLE CONTAINER. S. Tachibana[1,2], K. Sakamoto[2], M. Masuda[1], S. Inada[1], Y. Tsuruoka[1], H. Enomoto[1], S. Furuya[1], M, Nishimura[2], S. Yamanouchi[3], M. Abe[2], T. Usui[2], R. Okazaki[4], and H. Sawada[2], [1]Dept. Earth Planet. Sci., University of Tokyo, 7-3-1 Hongo, Tokyo 113-0033, Japan (tachi@eps.s.u-tokyo.ac.jp). [2]Inst. Space Astronaut. Sci. (ISAS), JAXA, 3-1-1 Yoshinodai, Sagamihara, Kanagawa, 252-5210, Japan. [3]Research Equip. Develop. Center of Sci. Faculty, Kyushu Univ., 744 Motooka, Fukuoka 819-0395, Japan [3]Dept. Earth Planet. Sci., Kyushu Univ., 744 Motooka, Fukuoka 819-0395, Japan.

Introduction: The JAXA's Hayabusa2 spacecraft explored Cb-type near-Earth asteroid (162173) Ryugu including two touchdown operations for sample acquisition [1, 2] to investigate the origin and history of the carbonaceous asteroid in the context of the Solar System evolution [3].

The spacecraft returned its reentry capsule in the Woomera Prohibited Area, South Australia on December 6, 2020. The sample container [4, 5] inside the reentry capsule was opened in the Hayabusa2 clean chamber system [6] on December 14, 2020, and particles collected from the first touchdown site were found in the sample catcher (a canister to store the sample inside the sample container) on December 15, 2020. During the preparation operation of the sample container opening from December 8 to 11, two millimeter-sized particles with a black hue were found in the gap between the sample container and its lid [7]. Detailed mineralogical and petrological investigation of these grains (called Q (*questionable*) particles) showed that Q particles (Q001 and Q002) have the same characteristics as Ryugu particles and are distinct from CI chondrites [7]. This suggests that Q particles were expelled from the sample catcher before closing the sample container lid in space. The presence of the Ryugu particles expelled from the sample catcher may have affected the sealing ability of the container [6].

In this study we further continue to characterize sub-millimeter-sized particles collected from the swabs and wipers used to clean the gap between the sample container and its lid to identify what those particles are and if there were more Ryugu particles between the gap. Abundance, size, material type, and their mechanical properties will also provide useful information to find a cause(s) of a small amount of air leak into the sample container [8] and to design the container sealing mechanism in future sample return missions.

Experimental: The gap between the container and the lid, outside of the container sealing face, was wiped with plastic swabs and dry wipers in the clean room at ISAS, JAXA on December 10, 2020. The swabs and wipers, kept in sealed aluminum bags in the clean room after cleaning, were examined in the clean room, and ~250 sub-millimeter sized particles were identified by naked eye.

The particles were individually picked up by electrostatic adhesion using a tungsten carbide needle and were fixed on two cupper plates using a small amount of glue following the procedure developed for micrometeorites [9]. The particles were then observed under a stereomicroscope at ISAS, JAXA and by a scanning electron microscope (JEOL JCM-7000) at U. Tokyo. The area analysis of chemical compositions of the particles were also made by energy dispersive spectroscopy (EDS) equipped with JCM-7000.

Results: Among 247 particles, we found 194 particles show textural features resembling Ryugu particles. Many of such particles have hexagonal iron sulfides and framboidal iron oxide (most likely magnetite) (Fig. 1). Their elemental compositions are within the range of those determined by multiple area analyses of Q001 particles in most cases (Fig. 2). Exceptions reflect heterogeneous distribution of minerals such as sulfides, magnetite, and carbonates. Textural, mineralogical, and chemical similarities to Ryugu sample led us to conclude that these sub-millimeter particles found on the swabs and wipers are also Ryugu particles that were expelled from the sample catcher in space before the container closing.

The other 53 particles show no similarity to Ryugu particles (Fig. 3). They are aluminum metal, stainless steel, carbonaceous materials (fibers in some cases), and most likely dessert sand, where the capsule landed. These are thus contaminants from the capsule, the landing location, the temporal laboratory space built in Woomera, and the clean room at ISAS, JAXA.

Implication: The presence of tiny but numerous Ryugu particles outside the sealing face indicates that some of such particle may have been present in the metal sealing edge of the sample container. 194 Ryugu particles in the gap (~38 cm^2 in area) suggests the average grain number density of ~5 cm^{-2}, corresponding to ~10 sub-mm-sized particles at the container sealing face ~1 mm in width ($2\pi \times 2.7$ [cm] ×0.1 [cm] ×5 [cm^{-2}]). Although such particles should have been wiped away by an aluminum sweeping foil before the container closing [5], those particles may have become the cause of a small amount of air leak (~2.5 Pa/h) [8]. However, we note that the minor leak of the container resulted in the exposure of grains to ~30-40 Pa of air for

~30 hours, corresponding to the exposure to the 1-atm air for 30-40 seconds. This amount of leak did not seriously damage to the Ryugu particles as shown in the preliminary examination [e.g., 10-15]. Detailed observation of the container sealing face is planned to find the cause of minor leakage.

The contaminants found in the swabs and wipers have not been found obviously in the analysis of Ryugu samples that were stored in the sealed sample container [e.g., 10-15]. This shows that the metal sealing system of the sample container worked as planned [4, 5] to minimize particle contamination.

References: [1] Morota T. et al. (2020) *Science 368,* 654–659. [2] Tachibana S. et al. (2022) *Science 375,* 1011–1016. [3] Tachibana S. et al. (2014) *Geochem. J. 48,* 571–587. [4] Sawada H. et al. (2017) *Space Sci. Rev.208,* 81–106. [5] Okazaki R. et al. (2017) *Space Sci. Rev. 208,* 107–124. [6] Abe M. (2021) in *Sample Return Missions* (ed. A. Longobardo), pp. 241–247. [7] Nakato A. et al. (2022) *Geochem. J. 56,* 197–222. [8] Okazaki R. et al. (2022) *Sci. Adv. 8,* eabo7239. [9] Sakamoto K. et al. (2010) *Meteorit. Planet. Sci. 45,* 220–237. [10] Yokoyama T. et al. (2022) *Science,* eabn7850. [11] Nakamura T. et al. (2022) *Science,* eabn8671. [12] Noguchi T. et al. (2022) *Nat. Astron.* 10.1038/s41550-022-01841-6. [13] Okazaki R. et al. (2022) *Science,* eabo0431. [14] Yabuta H. et al. (2023) *Science,* in press. [15] Naraoka H. et al. (2023) *Science,* in press.

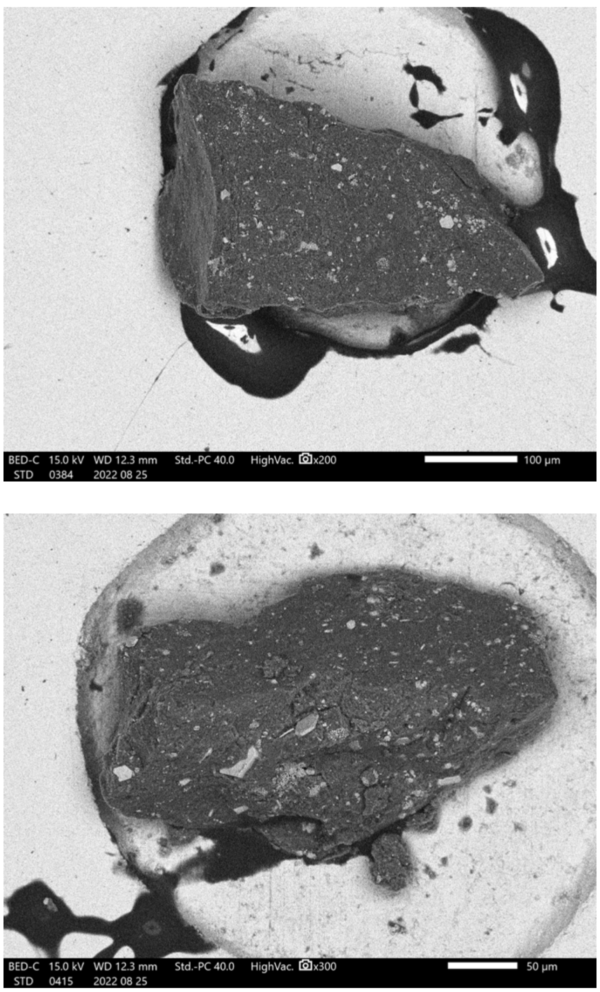

Fig. 1. Back scattered electron images of (possibly) Ryugu particles found from the swabs and wipers that used to clean the gap between the Hayabusa2 sample container and its lid.

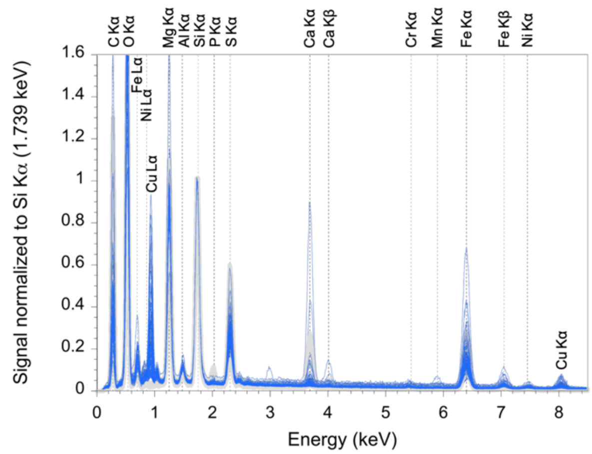

Fig. 2. Elemental compositions of (possibly) Ryugu particles (blue curves) compared with the range of area analyses of Q0001 shown in gray [7].

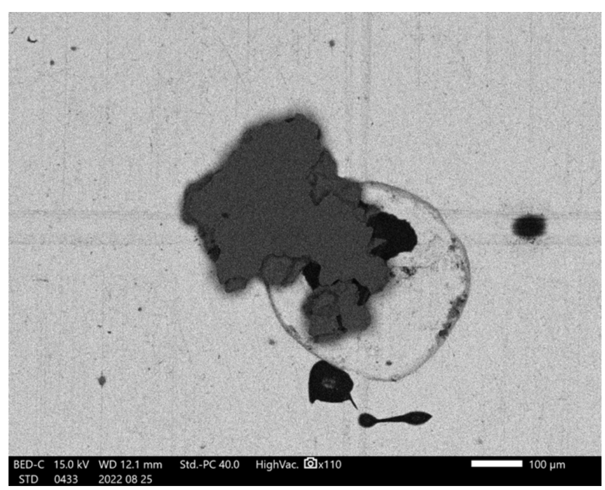

Fig. 3. An aluminum metal particle (contaminant) found on the swabs and the wipers.