Thermophysical property of the artificial impact crater on asteroid Ryugu

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The Hayabusa2 spacecraft has completed the rendezvous phase around Cb-type asteroid Ryugu in 2019. From thermal infrared imaging by TIR, global temperature distribution of Ryugu is consistent with the thermal calculation with thermal inertia of 300±100 J m^{-2} K^{-1} $s^{-0.5}$ [1], and thermal inertia values of the floors of craters are in general roughly comparable with the global average [2]. On the other hand, few small craters show anomalously low thermal inertia about 50 J m^{-2} K^{-1} $s^{-0.5}$, which might be contributed from the thermal insulating nature of the fine-grained and unconsolidated materials [3]. However, it is unknown how relaxation process of the crater relates to the thermophysical property and physical condition of the surface materials. On April 2019, Hayabusa2 have carried out an artificial impact (Small Carry-on Impactor or SCI) experiment [4], whereby a ~2 kg mass was fired at 2 km/s against the asteroid surface. As a result of the successful operation, an artificial crater (SCI crater) with diameter larger than 10 m was created on the asteroid. In this study, we investigated thermal property of the SCI crater as the freshest crater on Ryugu.

We had acquired TIR images of the SCI crater in some descending sequences (PPTD-TM1A&B operations on May and June, 2019). All of these images showed higher temperature in the SCI crater than surroundings by ~10 K, especially on the western side of the crater. This high temperature would indicate low thermal inertia materials in the crater, or the high solar incident angle on the crater inner wall would make the temperature higher.

Since the number of images and observation duration were limited for each operation, we could not examine diurnal temperature profile of the crater. In order to estimate the thermal inertia of the SCI crater from single thermal image, we conducted surface temperature simulation using a local digital elevation model (DEM) around the SCI crater. With varying thermal inertia, the simulated images were produced, and thermal inertia was estimated by comparison with the simulation results and observed temperature images.

As a result, the simulated temperature distribution inside the SCI crater agrees well with the observed image. In this preliminary analysis, we expect that the thermal inertia in the SCI crater is uniformly about 300 J m^{-2} K^{-1} $s^{-0.5}$, consistent with large boulders (Iijima boulder and Okamoto boulder) in the crater, surrounding materials, and the global average. Therefore, the chief determinant of the high temperature in the SCI crater would not be the change of the thermal inertia.

Diurnal thermal skin depth of Ryugu is a few centimeters, assuming the thermal inertia of 300 J m^{-2} K^{-1} $s^{-0.5}$. Although the inside of the SCI crater seems to be filled with finer grains than the surroundings [4], less change in thermal inertia of the SCI crater compared with the surroundings or top-surface large boulders indicates that the typical grain size of the subsurface layer (meter-scale in depth) is larger than a few centimeters. Furthermore, since the centimeter-sized grains have thermal property consistent with the larger boulders and the small grains are considered to be crushed from the large boulders, the thermophysical property of the boulders is expected to be homogeneous in centimeter-scale or larger.

References: [1] Okada et al. (2019), *Proc. Asteroid Science in the Age of Haya-busa2 and OSIRIS-REx*, #2092. [2] Shimaki et al. (2019), *Proc. Asteroid Science in the Age of Haya-busa2 and OSIRIS-REx*, #2050. [3] Sakatani et al. (2019), *Proc. Asteroid Science in the Age of Haya-busa2 and OSIRIS-REx*, #2189. [4] Arakawa et al. (submitted).