Thermal infrared observation of hot ejecta and impact crater on porous ice formed by high-velocity impacts

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Introduction

Recent planetary explorations and astronomical observations revealed that comet nuclei have high porosity. When a small body impacts on a porous body, large amount of heat would be deposited around the crater due to dissipation of impact energy accompanied with rapid attenuation of impact pressure; the deposited heat is named post shock heat. The post shock heat might promote the degassing of volatiles locally. Moreover, a melt pond might be formed under the crater on comets due to the post shock heat, and hydro alteration of materials might be promoted in the melt pond. Accordingly, the post shock heat is one of the most important heat sources on comets. But the amount of post shock heat deposited into a porous target was not well understood because the post shock heat around the crater on comets was not studied experimentally. To obtain the amount of the heat, we have investigated the temperature distribution caused by the post shock heat inside the target through in-situ observation: we measured the temperature distribution inside the porous icy targets impacted at a high velocity in our previous study. However, we could not measure the surface temperature of the crater wall previously. In this study, we observed the target surface using an infrared high-speed camera to measure it. As a result, we could obtain the temperature distribution of molten layer on the crater wall and measure the temperature of ejecta excavated from the target.

Methods

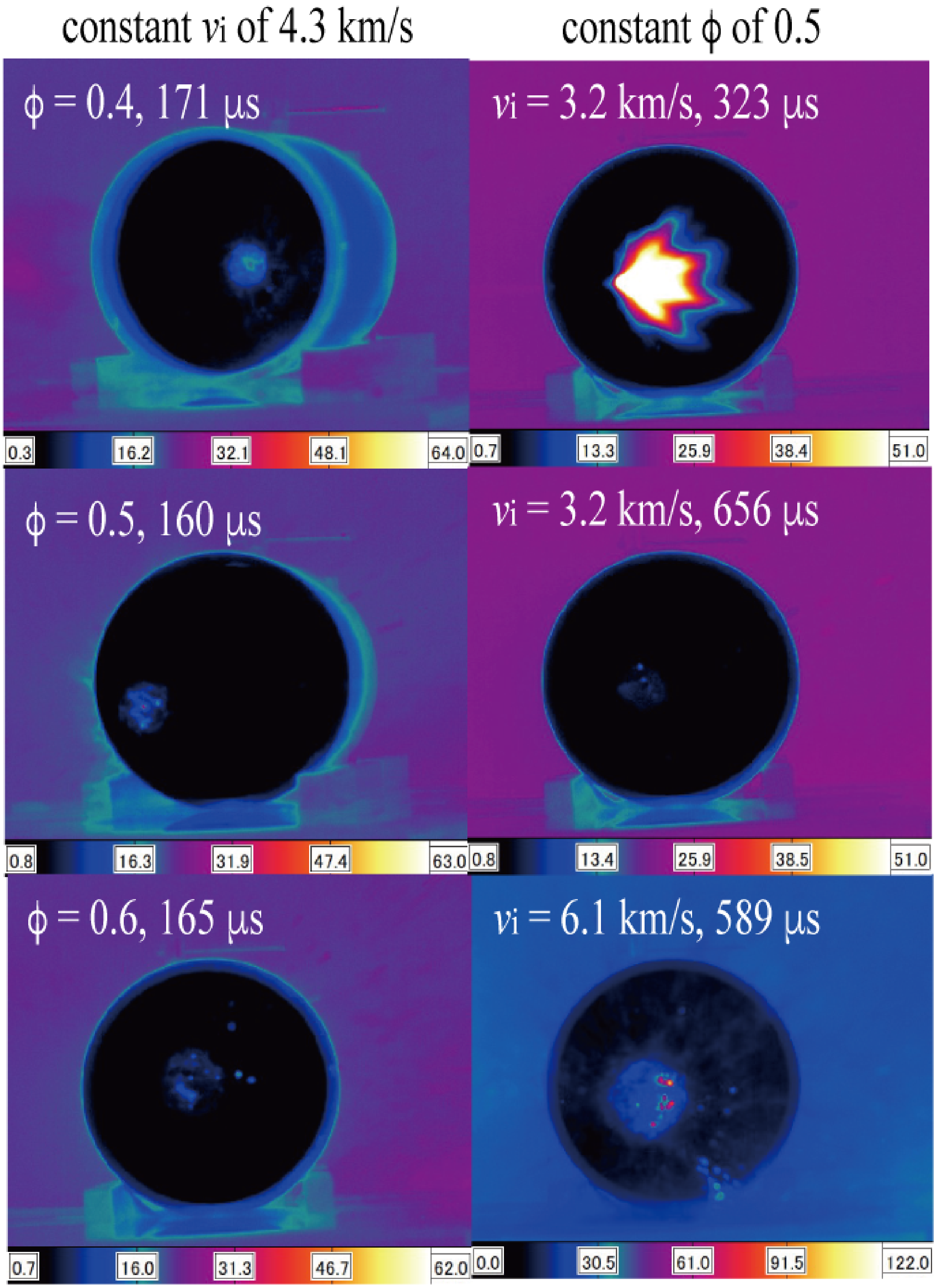
We conducted high-speed impact experiments on porous icy targets and measured the target surface temperature using an infrared high-speed camera. The porous icy target is the aggregate of ice grains with the porosity, Φ, of 0.4, 0.5 and 0.6. The target was stored in a freezer at -20 ºC and put in a vacuum chamber at room temperature just before the experiment. Then, the target was impacted at about 600 Pa. All experiments were done by using a two-stage light gas gun (JAXA). An aluminum sphere with the diameter of 2mm was used as a projectile and an impact angle was set to be about 45º. The impact velocity, $v_{i,}$ was set to be v_i = 4.3 km/s for Φ= 0.4 and 0.6, and v_i = 3.2, 4.3 and 6.1 km/s for Φ= 0.5. The infrared high-speed camera was placed in front of the target. The exposure time and the shutter speed of the camera were set to be 20 ms and 3,000 fps.

Results

Water vapor plume. Figures show snapshots just after the impact taken by the infrared high-speed camera. At Φ= 0.5 and v_i = 3.2 km/s, hot gas can be seen on the circular black area showing the target surface at 323 ms: The gas temperature exceeds 100 ºC. Therefore, this hot gas could be a water vapor plume ejected from impact point. This is the first confirmation that water vapor erupts from a porous ice target during the crater formation.

Temperature of the crater wall. The blue circular area with a high temperature was found in these figures, which corresponds to the crater wall or a part of it. At the constant v_i of 4.3 km/s, the temperature of the crater wall increased up to ~ 10 ºC irrespective of the target porosity. Furthermore, the temperature distribution was uniform over a wide area of the crater wall. On the other hand, at the constant $\Phi$of 0.5, the temperature of the crater wall increased up to about 4 ºC at 656 ms for v_i = 3.2 km/s and about 15 ºC at 589 ms for v_i = 6.1 km/s. Therefore, the crater wall could be melted and the temperature was at least a few tens of degrees. This value is consistent with the temperature of the crater wall which extrapolated from our previous study.

Keywords: comet, icy bodies, porosity, impact, post shock temperature


constant vi of 4.3 km/s
constant ϕ of 0.5
ϕ = 0.4, 171 μs
vi = 3.2 km/s, 323 μs
0.3
16.2
32.1
48.1
64.0
0.7
13.3
25.9
38.4
51.0
ϕ = 0.5, 160 μs
vi = 3.2 km/s, 656 μs
0.8
16.3
31.9
47.4
63.0
0.8
13.4
25.9
38.5
51.0
ϕ = 0.6, 165 μs
vi = 6.1 km/s, 589 μs
0.7
16.0
31.3
46.7
62.0
0.0
30.5
61.0
91.5
122.0

