SHOCK MELTING FEATURES IN REGOLITH PARTICLES OF S-TYPE ASTEROID ITOKAWA.

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Introduction: Impact-induced modification is a fundamental process that can alter mineralogical and petrographic features of asteroidal materials. The Hayabusa spacecraft recovered regolith samples from a S-type asteroid Itokawa. Itokawa is a ruble-pile asteroid that was formed by gravitational re-accumulation after a catastrophic impact event of its parent body [1]. The regolith particles from Itokawa are considered to be impact fragments formed on Itokawa [2]. The Itokawa regolith samples record a moderate shock history of Itokawa's materials [3-5]. In addition, Itokawa samples might have important information about impact events related to regolith alternation such as space weathering, lithification, and volatile loss from asteroids. Although shock features of crystalline minerals in Itokawa particles have been reported by many authors [3-5], there are few studies about melting textures of Itokawa samples [6]. In this study, we investigated shock veins and a large impact splash melt found among Itokawa particles.

Methods: Itokawa particles examined in the present study are RA-QD02-0275 and RA-QD02-0292. We observed the Itokawa particles by a scanning electron microscope (SEM: Hitachi SU6600). After SEM observation, the Itokawa samples were coated by carbon. Then, the particles were coated with platinum using a focused ion beam (FIB) system (FEI Helios G3, Quanta 3D FEG, Quanta 200 3DS). We extracted electron-transparent sections from regions of interest by milling with a Ga^+ beam. The electron transparent sections were analyzed by transmission electron microscopes (TEM: JEOL JEM-3200, FEI Tecnai G^2 FEG, JEOL JEM-2100F) equipped with EDX.

Results: RA-QD02-0275 consists of an olivine fragment of approximately 46 µm × 86 µm ×120 µm in size. A largest splash melt covers approximately 6.8×10^2 µm^2 of the olivine surface. The outline of the splash melt is irregular and wavy. A vertical section of the splash melt showed that multiple layers of Mg-rich silicate melt and iron sulfide alternate in the splash melt. The Mg-rich silicate melt layer is composed of amorphous silicate glass that contains numerous nanophase FeS particles of several nm to 150 nm in size. The composition of the silicate melt ($Wo_{0.9-2.8}En_{72-76}Fs_{20-26}$) is similar to low Ca pyroxene in LL chondrites. A single orthopyroxene grain ($Wo_2En_{77}Fs_{21}$) was found in the silicate melt, which is presumably a remnant that has not been melted. The pyroxene grain has parallel stacking faults and solar flare tracks. The density of the tracks is up to 4×10^{-9} cm^{-2}, which is higher than the track density of the substrate olivine, where tracks are rarely observed. The distinct track densities suggest their different irradiation histories prior to the melt formation. The iron sulfide layers are polycrystalline and have high Fe/S ratio up to 2.3 compared to troilite (Fe:S = 1:1) that is a major sulfide phase in Itokawa samples. Many bright spots (< 20 nm) in the Fe-S layer in z-contrast images. They are possibly Fe metals and may increase the average Fe/S ratio of the sulfide layer.

RA-QD02-0292 is a olivine grain of approximately 70 µm in size. Numerous mineral fragments up to 5 µm in size are aggregated on the host olivine. The fragments consist of olivine, pyroxene, plagioclase, and iron sulfide. TEM observation of thin sections including the fine fragments revealed that silicate melt veins are distributed across the fine fragments. The silicate melt vein contains abundant nanophase FeS. The width and length of the silicate veins are approximately 700 nm and 10 µm, respectively. In addition, there is a sulfide vein filling cracks of silicate fragments.

Discussion: Local silicate melt-glass with submicron-sized particles of FeS and Fe metal have been observed in powders of a L6 ordinary chondrite recovered from shock experiments, when the shock pressure is higher than 38 GPa [7]. Besides this, silicate melt veins containing FeS particles have been found in ordinary chondrites [e.g., 8]. Melting textures in Itokawa grains seems consistent with the shock melting features in ordinary chondrite materials. The high Fe/S ratio of iron sulfide layers in the melt splash indicates sulfur loss during melting and metal formation. Nanophase FeS particles are expected to alter reflectance spectra in the same manner as $npFe^0$ in lunar regolith [9]; nanophase FeS up to 150 nm in size in melts could cause spectral reddening and darkening. Impact melts could contribute to spectral change of larger S-type asteroids, where more extensive impact melting might occur compared to the surface of Itokawa.

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