Asteroid 25143 Itokawa Dust Particles: Mineralogy and Chondrite Affinities

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In the third international announcement of opportunity (AO3) for Hayabusa mission sample investigation, we received three dust particle samples. Two specimens are polished sections of post-analyzed particles embedded in resin: RA-QD02-0011-02 (~30 µm) and RA-QD02-0048 (~20 µm) with Au- and C-coatings, respectively (Figure 1). The third sample is a pristine particle, RB-CV-0083 (~95 µm). Particle RA-QD02-0011-02 was originally described to be mainly composed of olivine, low-Ca pyroxene, high-Ca pyroxene, and plagioclase [1-4]. In this study, the morphology and composition of the particles were inspected by means of (1) field emission scanning electron microscopy (FESEM), and associated energy-dispersive X-ray microanalysis (EDS) and electron back-scattered diffraction (EBSD) using an Hitachi SU-70 with Schottky type field emission gun, and (2) micro-Raman spectrometry at the Planetary and Space Science Centre (PASSC), University of New Brunswick, Canada.

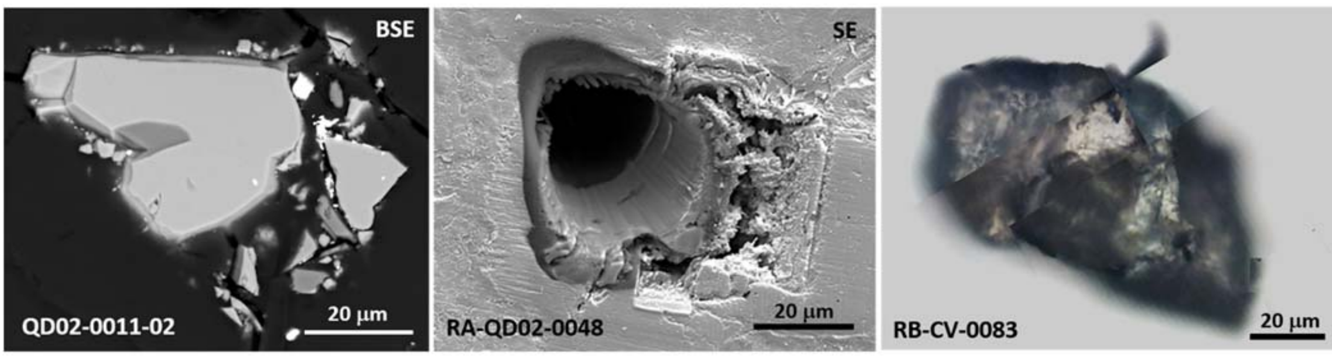
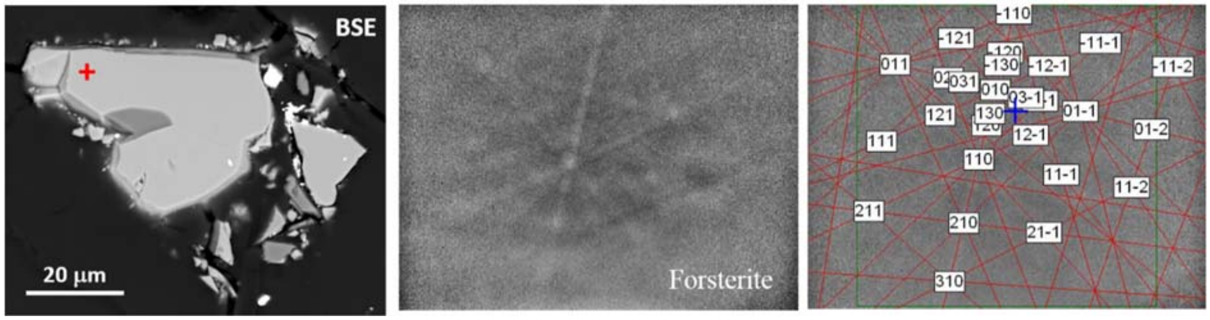
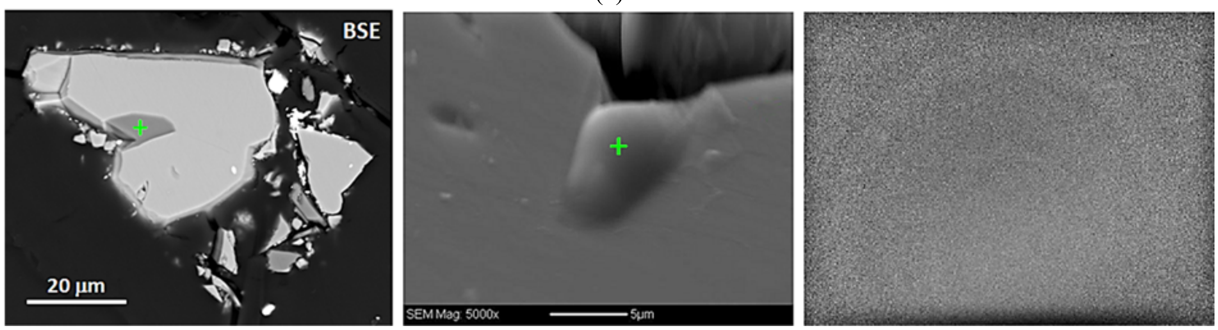


Figure 1. The three assigned Itokawa dust particles RA-QD02-0011-02 (~30 µm), RA-QD02-0048 (~20 µm), and RB-CV-0083 (~94 µm) provided by the Japan Aerospace Exploration Agency (JAXA) Hayabusa asteroidal sample return mission for this study.

The particles were collected from the surface of the S-type asteroid 25143 Itokawa. The particles comprise olivine, pyroxene and plagioclase. Fe-Ni metal, troilite (FeS), and chromite are also present. Energy dispersive spectrometry reveals that the olivine is $Fo_{70,}$ and the plagioclase is ($Ab_{81}An_{13}Or_6$). The plagioclase is interstitial to the olivine. The EBSD pattern of the $(Mg,Fe)SiO_4$ phase in RA-QD02-0011-02 matches well with the pattern of the orthorhombic crystal structure of forsterite with space group *Pbmn*. The unit cell dimensions are a = 4.76 Å, b = 10.21 Å, c = 5.98 Å, α = 90.0º, β = 90.0º, γ = 90.0º (Figure 2a). Raman analysis of the olivine reveals high intensity Raman bands at 819 and 851 cm^{-1}, with a Raman band calculated Fo number of 70 (Figure 3a). In addition, the $(Na,K,Ca)(AlSi)_4O_8$ phase next to olivine yields a typical EBSD pattern of amorphous material (Figure 2b). Raman analysis of the plagioclase reveals a broad band of amorphous material with an intense Raman band of crystalline phase albite/oligoclase. Both EBSD and the Raman results suggest that plagioclase was partially transformed to maskelynite (feldspathic glass). Intense Raman bands at 678, 659, 334 and 1006 cm^{-1} of orthopyroxene were obtained from RB-CV-0083. A cluster of forsterite ($Fo_{68.7}$), augite and plagioclase ($Na_{0.81}Ca_{0.12}K_{0.06}(Al,Si)_4O_8$) present at the rim of the particle. A microcrystal (~5 um diameter) of rounded, unzoned forsterite ($Fo_{69.5}$) with a nano-lath of albite/oligoclase (~1.0 µm x 500 nm) occurs in dust particle RB-CV-0083. The Mg/(Mg+Fe+Ca) ratio in pyroxene based on Raman band recalculation (678 and 334 cm^{-1}) is 0.7 (En_{70}) (Figure 3b), which is in good agreement with the EDS results ($Wo_3En_{73}Fs_{24}$). The olivine and orthopyroxene compositions are consistent with those of an LL4-6 chondrite. The presence of maskelynite suggests that the particles experienced shock metamorphism. The compositional homogeneity of olivine and the development of plagioclase indicate that the petrologic type of Itokawa dust particles is derived from a highly equilibrated chondrite. Our study confirms that the analyzed Itokawa dust particles are from a shocked equilibrated LL4-6 chondrite that now forms part of the asteroid's regolith. The source of the dust particles remains conjectural in that they could be from fragmented projectiles that impacted Itokawa, or from excavated material from within Itokawa, which itself is probably an assemblage of multiple asteroid components. The presence of maskelynite strongly suggests that the asteroid experienced shock impact during its evolution.

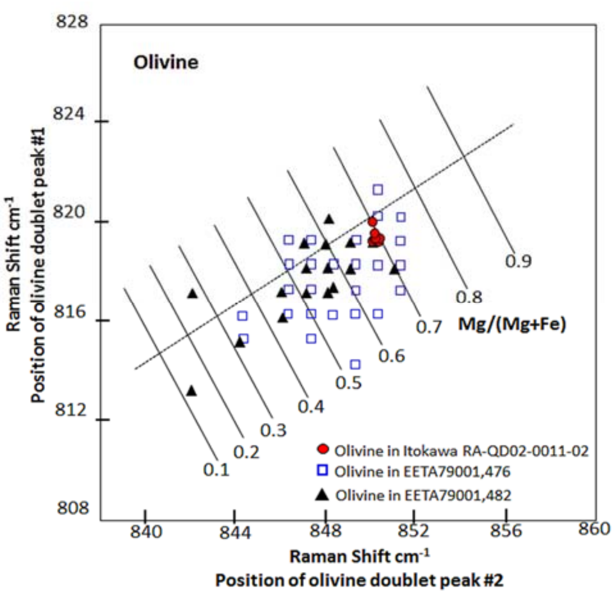


(a)

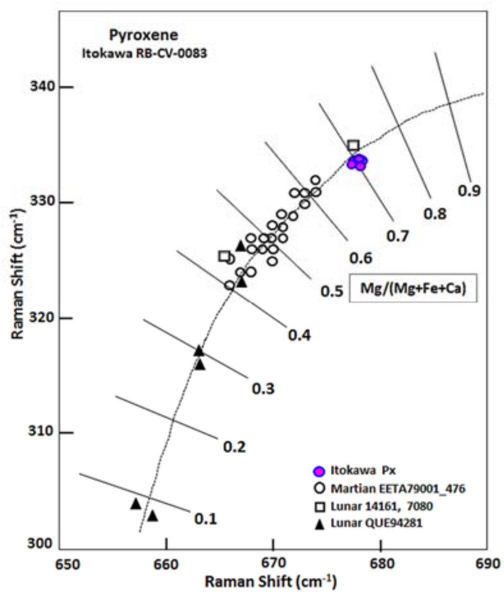


(b)

Figure 2. (a) The EBSD pattern of the (Mg,Fe)SiO_4 phase in RA-QD02-0011-02 matches well with the pattern of the orthorhombic crystal structure of forsterite (*Pbmn*) with unit cell dimensions a = 4.76 Å, b = 10.21 Å, c = 5.98 Å, α = 90.0º, β = 90.0º, γ = 90.0º. (b) Electron backscattered diffraction patterns (EBSD) of (Na,K, Ca)AlSi3O8 phases shows an amorphous EBSD diffraction pattern in the absence of Kikuchi bands.



(a)



(b)

Figure 3. (a) The Raman peak positions at 851 and 819-820 cm^{-1} of olivine in Itokawa sample RA-QD02-0011-02 (red dots) are plotted on a diagram of peak positions of its charcteristic Raman modes of olivine [5]. The data points fall along the calibration line suggesting the Mg/(Mg+Fe) value for the Itokawa olivine ~0.7 (Fo_{65-70}). (b) The data for a pair of peak positions of characteristic Raman modes (678 and 334 cm^{-1}) for orthopyroxene from RB-CV-0083 are plotted on the curve (pink dots), which corresponds to Mg/(Mg+Fe+Ca) molar fraction in pyroxene values of 0.7 (En_{70}) [6].

References

[1] Yurimoto et al. 2011. Science. 333, 1116-1119. [2] Nakamura et al. 2011. Science 333, 1113-1116. [3] Tsuchiyama et al. 2011. Science. 333, 1125-1128. [4] Yada et al. 2012. Japan Aerospace Exploration Agency, Japan, unpublished document. [5] Wang et al., 2004. J. Raman Spectrosc. 35, 504-514 [6] Huang et al., 2000. Am. Mineralogist 85**,** 473-479.