Petrography and TEM study of two Itokawa particles.

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Introduction: A strong link between Itokawa particles and LL chondrites is confirmed by preliminary examinations and the first AO of Hayabusa particles [e.g., 1, 2]. The presence of poorly equilibrated and highly equilibrated particles has been found for Itokawa particles [1], and they correspond to LL4 and LL5-6, respectively. Here we report the petrography of two allocated Itokawa particles and TEM study on one particle, and compare them to 10 Antarctic LL chondrites with variable petrologic types (LL4-LL7) in order to understand the metamorphic history of asteroid Itokawa.

Methods: Two allocated particles RA-QD02-0094 (0094) and RA-QD02-0127 (0127) were studied. Each particle embedded in epoxy following the method by [1, 3] was then polished for optical microscope and FEG-SEM observations. After EPMA analyses, two TEM sections were prepared from the particle 0094 using an FIB technique.

Results: *RA-QD02-0094:* This particle is 50 μm × 30 μm in size, composed of olivine and FeS (<20 μm). A single crystalline olivine is easily recognized under microscopic observation, and no undulatory extinction was observed indicating low grade of shock. Olivine shows a homogeneous composition (Fo_{70}). In comparison with LL 4-7 chondrites in this study, the FeO and MgO contents of 0094 is similar to LL6 and LL7. Two submicron-sized chromite grains enclosed in olivine are also observed. Chromite grains are too small to be analyzed by EPMA, but the Fe/Cr atomic ratio obtained from SEM-EDS analysis is similar to those of chromite grains characterized in previous study [1].

Two FIB sections are made from the 0094 particle. TEM analyses show that both olivine and FeS grains are single crystals. There is no orientation relationship between FeS and olivine. No planar defects are observed in olivine, suggesting that 0094 experienced shock stage of S2 [4] or lower. The low degree of shock in the equilibriated Itokawa particles is consistent with other studies (e.g., [3]).

RA-QD02-0127: This particle is 50 × 45 μm in size. It is composed of olivine (Fo_{72-75}), low-Ca pyroxene ($Fs_{19-24}En_{76-80}Wo_{0-2}$), and plagioclase ($An_{7-10}Ab_{90-94}$). Fine-grained high-Ca pyroxene($Fs_{10-12}En_{58-59}Wo_{29-32}$) and FeS grains are also identified. Because each grain is small, chemical compositions are collected only with SEM-EDS analyses so far. Although we need more data to conclude the metamorphic degree for 0127, chemical compositions of olivine/pyroxene and the size of plagioclase grains are similar to those in poorly equilibrated particles in [1], indicating that the 0127 grain has originated from the area which corresponds to LL 4-5 chondrite.

Conclusion: The combination of LL6/7-like (equilibrated) and LL4/5-like (unequilibrated) particles indicates that rocks with different metamorphic histories are in close proximity on the surface of Itokawa, suggesting regolith gardening after parent body metamorphism.

References: [1] Nakamura T. et al. 2011. *Science* 33:1151–1154. [2] Yurimoto H. et al. 2011. *Science* 33:1116-1119. [3] Mikouchi T., et al., 2014 *EPS* 66:82.[4] Stöffler D. et al.,1991. *GCA* 55: 3845-3867.[5] Van SchmusW.R. and Wood J.A. 1967.*GCA* 31: 747-565.[6] Kovach H.A.&Jones R.H. 2009.*MAPS* 45:246-264.