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Shock state of the Itokawa samples

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Introduction: One of the fundamental aspects of any astro-material is its shock history [1]. The Hayabusa Preliminary Examination Team (HASPET) made shock stage determination of the Itokawa samples a primary goal [2]. The shock state of ordinary chondrite materials is generally determined by simple optical petrographic observation of standard thin sections, which we also did here. We made an additional estimation of the sample shock state by electron back-scattered diffraction (EBSD). We are also investigating the crystallinity of Itokawa olivine by synchrotron X-ray diffraction (SXRD).

Results: We made EBSD maps of 6 equilibrated (LL5/6) Itokawa. The EBSD maps revealed that olivine crystallinity varies considerably within the space of a few micrometers, and likewise albite, troilite and chromite. Albite was sometimes better crystalline than adjacent olivine, counter to our expectations. However, local variations in degree of crystallinity is a hallmark of shock metamorphism [1,4]. In order to determine the relative shock degree of the Itokawa grains we duplicated the EBSD analysis using grains from the Kilabo LL6 (shock stage S3) and Alfianello L6 (S5) ordinary chondrites. We used completely equilibrated type 6 chondrites in order to avoid potential complications from variable mineral compositions. By visually comparing the overall crystallinity of samples from EBSD and Band Slope maps we estimated that Itokawa samples should be assigned to be intermediate between Kilabo and Alfianello, therefore shock stage S4 by EBSD. We also determined the shock state of the Itokawa samples in the conventional manner under crossed polars in a standard petrographic microscope. Despite the irregular and non-standard specimen thickness this was surprisingly easy to do. We examined 29 separate grains. Practically all crystallites in the Itokawa grains exhibited minor to pronounced undulatory extinction. Some grains displayed distinct mosaicism. We saw no instances of shock veins in the equilibrated (LL5-6) grains, but there were amorphous regions in the unequilibrated LL4 grains. We observed no obvious parting or planar deformation features. Given the natural variability of shock effects [1] , these petrographic observations indicate shock stage S2, which is considerably lower than that suggested by the EBSD images (S4). To verify that shock levels were lower than S4 we have begun collecting SXRD data on larger Itokawa olivine grains. Grain RA-QD02-0049-2 consists almost entirely of olivine, and its diffraction pattern was very sharp, indicating insignificant shock metamorphism for this particular grain.

Conclusions: Shock effects can be effectively studied from even the tiny Itokawa grains, and by multiple techniques. It would be interesting to examine IDPs and lunar regolith grains in the same manner. However, EBSD and standard petrographic techniques are not equally sensitive to very fine-scale shock effects. EBSD appears to have greater potential to elucidate shock effects at the finest scale, but if EBSD data only are used to assign a shock stage these results may not be directly comparable to those obtained by standard petrographic techniques.

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