Quantitative shock stage evaluation of chondrites from X-ray diffraction: A new method

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1. Introduction

Stöffler et al. (1991) have established the shock stage classification of ordinary chondrites by the global textural observations and the shock recovery experimental results, which is defined to be S1 to S6. A further consideration, a quantitative analytical technique of shock effects on ordinary chondrites, is still much in concern. The mean lattice strain in main constituent minerals (olivine and orthoenstatite) is one of the primary parameters quantitatively for evaluating the shock history of the stony meteorites (e.g., Uchizono et al., 1999; Imae 2019). However, this was not enough since the shock effect also appears as mechanical destruction of grains, and this may be reflected in the decrease of the crystallite sizes. In the present study, the X-ray diffraction of L6 ordinary chondrites with a single lithology (the shock stage = S1-S5) were obtained from the in-plane rotation method of the polished thin sections (PTSs). Then the obtained diffraction was successfully analyzed, focusing on the mean lattice strains and crystallite sizes of olivines and orthoenstatites. The new analytical technique would generally be suitable for the quantitative shock classification of stony meteorites.

2. Experiments

Using X-ray diffractometer (SmartLab, Rigaku), PTSs for 14 L6 chondrites (9 Antarctic and five non-Antarctic meteorites) were measured on the conditions of the scanned twofold Bragg angle in the range of 3-75º and the length limiting slit of 5 mm with the divergence angle of (1/6)º. The sample stage was rotated with a rate of 100 rpm during the measurements. Focused Bragg indices were 130, 211, 222, and 322 for olivines, and 610, 511, 421, 631, and 12 12 for orthoenstatites, since their indices are almost isolated peak.

3. Results and Discussion

The Williamson-Hall plot (Williamson and Hall, 1953) is given by tangent of the Bragg angle of the focused indices as the horizontal axis and the integral breadths (in the range of more than zero and much less than one degree) as the vertical axis. The plots for olivines and orthoenstatites of the measured samples showed good correlation factors >˜0.8-0.9 except for several. The mean lattice strain is obtained from the slope, and the crystallite size is from the reciprocal of the cross-section with the vertical axis. Then the mean lattice strains were in the range of 0.05 (S1) -0.25% (S6) for olivines, and those in 0.1 (S1) -0.4% (S5) for orthoenstatites. The crystallite sizes are sub-μm, decreasing from S1 to S6. Then the shock stage parameter is newly defined to be [strain /log (integral breadth at horizontal axis zero)]. The shock stage parameters for olivines and orthoenstatites are correlated with the shock stage by Stöffler et al. (1991).

4. Summary

The new shock stage parameter combing lattice strains with crystallite sizes is useful clearly for estimating the shock stage of stony meteorites.

5. References

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