Cubic-tetragonal transition of (Mg,Fe)SiO_3 majorite

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1. Introduction

Majorite is one of the major constituent minerals of the upper mantle. There is an inconsistency about the crystal symmetry of majorite between synthetic (tetragonal) and natural (cubic) majorite of meteorite origin, and this phase relation is not well known. Previously, cubic (Ia3d)-tetragonal ($I4_1/a$) transition of $MgSiO_3$ majorite was reported based on TEM observations. {101} and {110} twins are inferred to be caused by this transition[1]. Wang et al.[2] suggest that the modulated "tweed" structure in the cubic phase may also be regarded as a precursor of the cubic-tetragonal transition. In the viewpoint of planetary science also, the phase relation of Al-deficient majorite at high-pressure and temperature is important. Here, we report the phase transition of (Mg,Fe)SiO_3 majorite based on analytical electron microscope observations of synthetic and natural majorites.

2. Experiments

High-pressure and high-temperature experiments to synthesize (Mg,Fe)SiO_3 majorite were performed by a uniaxial split-sphere apparatus at Institute for Study of the Earth's Interior, Okayama University, Japan. The compositions of starting materials range from X=0 to 0.25 in (Mg_{1-x},Fe_x) SiO_3. The specimens were synthesized at 20 GPa and around 1950-2200°C. Quenched specimens were milled by Ar-ion and examined by an analytical electron microscope. Natural majorite in the shock-vein in Tenham chondrite was also examined.

3. Results and discussion

Synthetic majorite

The diffraction patterns of majorites in all the recovered specimens showed a tetragonal symmetry. In these majorites, {101} twin lamellae (Fig. 1), an isolated {110} twin domain and the tweed structures were observed. With Fe-bearing majorites, {101} twins were found in the specimens quenched from temperatures equal to or higher than 2000 °C, and the tweed structures from temperatures equal to or higher than 2200 °C. However, all these microstructures were not found in the specimens quenched from temperatures lower than 2000 °C. With $MgSiO_3$ majorite, there was a boundary around 1900°C below which majorite was twin-free.

These observations suggest that the high-density of {101} twin lamellae was derived from the cubic-tetragonal transition due to cation ordering in octahedral sites. The cubic (Ia3d) majorite seems to have a wide stability field at higher temperatures above the tetragonal ($I4_1/a$) majorite field. Cubic majorites would have transformed to the tetragonal phase when they passed across the cubic-tetragonal boundary during quenching.

Natural majorite

Natural majorites in the shock-vein occur as euhedral grains (<2 μm) with a certain amount of Al_2O_3 component (4.6 wt%). These majorites have a cubic symmetry and show neither twinning nor tweed structure. However, Al-free majorte as previously reported, has not been found. Twin-free natural majorite seems to support the hypothesis that twinning in synthetic (Mg,Fe)SiO_3 majorite was caused by cubic-tetragonal transition during quenching.

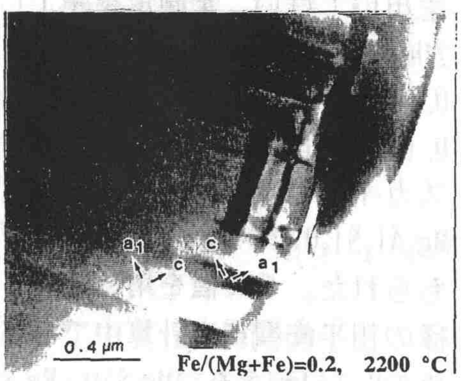

Fig. 1. {101} twin lamellae in synthetic majorite

References

[1] D. M. Hatch & S. Ghose, Am. Mineral., 74, 1221-1224 (1989) .

[2] Y. Wang, T. Gasparik, R. C. Liebermann, Am. Mineral., 78, 1165-1173 (1993).