

A new high-pressure polymorph of $(\text{Mg,Fe})_2\text{SiO}_4$ in a shocked L chondrite

*Naotaka Tomioka¹, Takuo Okuchi²

1. Kochi Institute for Core Sample Research, Japan Agency for Marine-Earth Science and Technology, 2. Institute for Planetary Materials, Okayama University

A new high-pressure polymorph of Mg_2SiO_4 was discovered in the Tehnam L6 chondrite by transmission electron microscopy (TEM). Tenham is one of the renowned meteorite samples containing various types of high-pressure silicate minerals within and in the vicinity of shock veins [1]. Based on the occurrence of high-pressure mineral assemblages reported in Tenham and experimental phase equilibrium studies, the peak shock pressure was estimated to be ~ 25 GPa [2].

Euhedral and subhedral ringwoodite (Fo_{69}) grains with sizes of 0.35 ± 0.2 μm occur as polycrystalline aggregates in a shock vein. These grains are crystallographically randomly oriented. Most of the ringwoodite grains exhibit pervasive planar defect on $\{110\}$ planes. These defects have been reported in ringwoodite from many shocked ordinary chondrites. Despite the typical microtexture, the detailed analysis of the respective grains revealed novel crystallographical features. Selected area electron diffraction (SAED) patterns of most of the grains of the ringwoodite aggregates show strong diffraction spots that are consistent with a spinel structure. In addition, weak diffraction spots were observed. These diffraction spots could only be indexed by a new spineloid structure which was previously theoretically predicted as “ ϵ^* -phase” in Mg_2SiO_4 polymorph [3]. High-resolution TEM showed that some of planar defects in the ringwoodite correspond to the ϵ^* -phase with a spacing below 10 nm. In addition, the SAED patterns of ringwoodite with ϵ^* -phase lamellae show that both phases have a topotaxial relationship: $(001)_{\epsilon^*} // (001)_{\text{Rwd}}$ and $(100)_{\epsilon^*} // (110)_{\text{Rwd}}$. The crystallographic relationship can be explained in terms of periodic arrangements of a basic unit of spinel and spineloid structures.

Olivine in the host rock of Tenham entrapped in the shock vein initially transformed into polycrystalline ringwoodite through a nucleation and growth mechanism. The ringwoodite grains then coherently converted into the ϵ^* -phase by shear transformation during subsequent pressure release. This intermediate metastable phase can be formed by all Mg_2SiO_4 polymorphs via a shear transformation mechanism [3]. Our discovery indicates that high-pressure transformations of olivine that are enhanced by diffusionless processes, not only in shocked meteorites but also in thick and cold lithosphere subducting into the deep Earth.

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