TOPOTAXIAL INTERGROWTHS OF EPSILON-(MG,FE)$_2$SIO$_4$ IN WADSLEYITE AND RINGWOODITE IN SHOCKED CHONDRITES.

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Introduction: Phase equilibria studies have demonstrated that olivine transforms into a spinelloid phase (wadsleyite) and then into a spinel phase (ringwoodite) with increasing pressure. Natural ringwoodite and wadsleyite were first discovered in heavily shocked ordinary chondrites [1, 2]. The defect structures in these olivine polymorphs were repeatedly characterized by transmission electron microscopy [e.g. 3–4]. Based on occurrences of stacking faults in these phases, shear-promoted diffusionless mechanisms were proposed in transformations among olivine, wadsleyite, and ringwoodite [4]. The transformation models also predicted the possible occurrence of an intermediate phase, named ‘ε-phase’, exhibiting the smallest unit cell among all spinel/spinelloid structures [4]. Although the ε-phase had been discovered neither in high-pressure syntheses products nor in natural samples, we recently found the phase in ringwoodite grains in the shocked chondrite Tenham [5]. In the present study, we present further characterization of the ε-phase based on transmission electron microscopy of meteoritic samples and the first principles calculations.

Experimental methods: Polished thin sections of Tenham (L6) and Miami chondrites (H5) were used in the present study. Aggregates of ringwoodite and wadsleyite in shock veins were extracted and processed into thin foils by Ar-ion milling (Gatan DuoMill model 600) and focused ion milling (Hitachi SMI-4050). The thin foil samples were examined using a transmission electron microscope (JEOL JEM-ARM200F). Crystal structure and stability of the ε-phase were evaluated by the first principles calculations based on the initial model of the ε-phase proposed by previous topological study [4]. The first-principles calculations were performed with *Quantum Espresso* codes [6] based on plane wave basis set, pseudopotentials, and a generalized gradient approximation [7] of density functional theory.

Results and Discussion: Tenham and Miami chondrites have shock veins containing the host rock olivine fragments that partially or totally transformed into its high-pressure phases. In Tenham, we examined submicron-sized ringwoodite grains occurring as polycrystalline aggregates in shock veins. These ringwoodite grains are crystallographically randomly oriented and exhibit pervasive planar defects on {110}. Despite the typical microtexture [4], the detailed analysis of the respective grains revealed novel crystallographical features. SAED patterns from most of the ringwoodite grains show weak extra diffraction spots corresponding to a new spinelloid structure theoretically predicted as ‘ε-phase’ in Mg_2SiO_4 [4]. In addition, the SAED patterns of ringwoodite with ε-phase lamellae show that both phases have a topotaxial relationship: $a_{\varepsilon}, b_{\varepsilon}//\langle 110 \rangle_{\mathrm{Rwd}}$ and $c_{\varepsilon}//c_{\mathrm{Rwd}}$. In Miami, wadsleyite also shows a similar occurrence to ringwoodite in Tenham. Many of the wadsleyite grains exhibit planar defects on (010). The wadsleyite with the ε-phase lamellae shows the following topotaxy: $a_{\varepsilon}//a_{\mathrm{Wds}}$, $b_{\varepsilon}//b_{\mathrm{Wds}}$, and $c_{\varepsilon}//c_{\mathrm{Wds}}$. The first principle calculations clarified all the atomic positions in the ε-phase structure is slightly displaced along *c*-axis from those in the ideal one. All the lattice vibrations of the ε-phase have real numbers in their phonon frequencies. This suggests dynamic stability of the ε-phase, although its *P-T* conditions of formation have yet to be understood. The above crystallographic relationships between ε-phase and ringwoodite/wadsleyite can be explained in terms of periodic arrangements of a basic unit of spinel and spinelloid structures. Olivine in the host rock of Tenham and Miami entrapped in the shock veins initially transformed into polycrystalline ringwoodite and wadsleyite through a nucleation and growth mechanism during shock compression. The ε-phase would have been produced by shear transformation from the ringwoodite and wadsleyite during the shock compression or subsequent shock pressure release.

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