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Mechanism of high-pressure phase transition in enstatite

Naotaka Tomioka[1], Kurt Leinenweber[2], Thomas Sharp[2]

[1] Earth & Planetary Sci., Kobe Univ., [2] Geological Scineces, Arizona State Univ

Phase transition mechanisms of silicate minerals under high-pressure and -temperature are important to understand the fate of subducting slab in the deep Earth and the shock metamorphism in chondrites. Therefore, the high-pressure transition behavior in olivine, being the most abundant mineral in the Earth's upper mantle and chondrites, has been well investigated. However, only a few studies on the high-pressure transition in pyroxene has been reported. In this study, we experimentally investigated the high-pressure transition mechanism in MgSiO3 pyroxene. High-pressure experiments were performed by a multianvil apparatus at Arizona State University. Coarse crystals of synthetic MgSiO3 enstatite (~200-500 micron), embedded in fine synthetic pure enstatite powder (less than 50 micron), were enclosed in a cylindrical rhenium heater. Firstly, the specimens were held at pressure 12 GPa at 1300 deg C for 3 hours to remove the elastic and the plastic strain in the samples formed during the compression at room temperature (hot-pressing). Only the run BB-73 (24 GPa, 1300 deg C) was done without hot-pressing stage. Subsequently, specimens were hold at the pressure range of 20-24 GPa and temperatures between 1250-1500 deg C for 0.17-2 hours. The recovered specimens were investigated by optical microscopy, Raman spectroscopy and transmission electron microscopy. Under the optical microscope, it is observed that large single crystals of enstatite in all specimens recrystallized into aggregates of finer grains (~10-100 micron) and those crystals orientated randomly. The Raman spectra from recovered specimens show ilmenite-phase formed in all the specimens. In the specimens from lower than 22 GPa, original enstatite partially transformed into ilmenite, but the interface between relict enstatite and ilmenite was ambiguous. Whereas, in the specimens recovered from the highest pressure near the ilmenite-perovskite phase boundary, part of former large crystal showed only spectrum of ilmenite. Additionally, electron diffraction patterns revealed that perovskite phase also formed. In the specimen BB-73 (24 GPa, 1300 deg C) without hot-pressing stage, there is no apparent difference in the reaction mode of enstatite. In this study, single crystal of enstatite in all specimens partly or mostly transformed into randomly oriented polycrystalline aggregate of high-pressure phases. Therefore, the transformation mechanism in MgSiO3 is the nucleation and growth at the studied P-T conditions. Recently, it is reported that the clinopyroxene-ilmenite transition in FeGeO3 is promoted by the shear mechanism at high overstepping pressure (Hatttori et al. 2001). Therefore, the shear mechanism in enstatite-ilmenite transition in MgSiO3 would occur at much higher pressures than in this study. Further transformation experiments at higher pressure are necessary to constrain the conditions of shear mechanism.