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Acoustic velocity measurements for stishovite across the post-stishovite phase transition under deviatoric stress: Implications for the seismic features of subducting slabs in the mid-mantle

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Abstract

Understanding effects of non-hydrostatic pressure on phase transitions in minerals relevant to the Earth's mantle is important to translate the observable seismic signals to not directly observable mineralogical models for the deep Earth. SiO_2 can occur as a free phase in subducting slabs, which contain sedimentary layers and/or mid-ocean-ridge basalts. In this study, we report on the effect of deviatoric strain on the pressure-induced phase transition in SiO_2 and its consequences on the seismic signal.

The acoustic velocity in polycrystalline stishovite across the post-stishovite phase transition was measured by Brillouin scattering in the pure SiO_2 system at room temperature under deviatoric stress. High-pressure synchrotron X-ray diffraction data were also collected at SPring-8. A linear fit to the symmetry-breaking strain values and the pressure of the transverse velocity minimum indicate a transition pressure between 25 and 35 GPa, which is about 20 GPa lower than that under hydrostatic conditions. The transverse velocity dropped by about 3% at around 25 GPa in this study. This is much smaller than the prediction from ab initio calculations that a transverse velocity reduces by ~60% at around 50 GPa under hydrostatic conditions. The results of the present study indicate that the deviatoric stress lowers the transition pressure and reduces the acoustic velocity change associated with the post stishovite phase transition. Sedimentary and mid ocean ridge basalt (MORB) layers in a subducting slab are likely sites for finding stishovite and its high-pressure polymorphs in the deep earth. Seismic observations of deep earthquakes occurring in subducting slabs indicate the existence of considerable stress in down-going slabs. This study suggests that nonhydrostatic deviatoric stress is one of the possible reasons for the absence of general seismic features that can be directly related to the post-stishovite phase transition in subducting slabs at 1500 km depth. The phase transition of stishovite under deviatoric stress, which occurs at shallower depths, can affect the local seismic scattering structures and the rheological behavior of a subducting slab in the mid-lower mantle region.

Keywords: High-pressure studies, stishovite, acoustic velocity, post-stishovite transition, deviatoric stress, subducting slab