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Stiffer than expected: high-pressure elasticity of polycrystalline stishovite questions seismic signature of deep silica

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Geophysical detection of chemical heterogeneities in Earth's lower mantle remains a critical task to trace deep geochemical cycles and to understand the dynamic evolution of the planet. Silica-rich material may be carried to the lower mantle by subduction or delamination of Earth's crust or, as recently proposed, exsolve from Earth's outer core. At conditions of the lower mantle, free silica phases may contribute with more than 10 vol-% to basaltic rocks. The displacive phase transition of tetragonal stishovite to an orthorhombic structure around 50 GPa has been predicted to cause a reduction in shear wave velocities in proximity to the phase transition. Consequently, seismically detected heterogeneities in the depth range matching the transition pressure of stishovite have been related to silica-rich material. However, the magnitude of the reduction in shear wave velocity has not been quantified experimentally for pure stishovite under hydrostatic compression. We performed X-ray diffraction and Brillouin spectroscopy experiments on sintered stishovite polycrystals up to pressures of 73 GPa and 60 GPa, respectively. Circular disks were cut from a double-sided polished thin section of a stishovite polycrystal using a focused ion beam and loaded into diamond anvil cells using neon as pressure-transmitting medium. X-ray diffraction patterns were recorded at beamline ID15 of the European Synchrotron Radiation Facility (ESRF). Brillouin spectra were collected in forward symmetric scattering geometry at Deutsches Elektronen-Synchrotron (DESY) and at Bayerisches Geoinstitut (BGI). While clearly revealing the tetragonal-to-orthorhombic phase transition by splitting of individual X-ray reflections and the concomitant emergence of spontaneous strain, our results indicate a smooth increase of shear wave velocities across the phase transition without significant reduction around the transition pressure. Instead, we observed a steady decrease in compressibility of the stishovite polycrystal approaching the transition pressure followed by a discrete increase in compressibility at the phase transition. This behavior differs clearly from observations on stishovite single crystals and powders. We tentatively attribute these differences to the complex elastic response of sintered polycrystals, which to a first approximation resemble rocks. To evaluate the seismic signature of silica in the lower mantle, we combined pressure-induced variations in unit-cell edge lengths and volume with those in shear wave velocities to a high-pressure elasticity model for tetragonal and orthorhombic stishovite. Using our results on stishovite and reported thermo-elastic parameters of mantle minerals, we calculate contrasts in seismic properties between basalt and pyrolite to assess the detectability of subducted material in Earth's lower mantle.