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Effect of Al^{3+} and H^+ on the elastic properties of stishovite

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Abstract

X-ray diffraction, Brillouin, and Raman scattering measurements were performed on Al^{3+} and H^+-bearing stishovite at ambient conditions. Samples with different Al^{3+} and H^+ contents were used to examine the effects of these minor constituents on the density, acoustic velocities, single-crystal and aggregate elastic moduli. The X-ray diffraction and compositional data suggest that the incorporation mechanism of Al^{3+} into stishovite involves the formation of oxygen vacancies, in addition to the incorporation H^+ in the structure. Our data show an overall linear decrease of the acoustic velocities, single crystal ($\boldsymbol{c}_{ij}$) and aggregate (K_0, G_0) elastic moduli as a function of Al^{3+} concentrations. For the sample of stishovite containing 6.07(5) wt% Al_2O_3 and 0.24(2) wt% H_2O we obtained: zero-pressure adiabatic bulk modulus, K_{S0} = 290(3) GPa, and the shear modulus, G_{S0} = 207(2) GPa, with a calculated density of ρ = 4.16(1) g/cm^3 based on X-ray diffraction. Stishovite containing 4.37(12) wt% Al_2O_3 and 0.29(3) wt% H_2O possesses higher aggregate moduli: K_{S0} = 296(3) GPa and G_{S0} = 213(2) GPa, with a calculated density of ρ = 4.21(1) g/cm^3 based on X-ray diffraction. We conclude that the formation of oxygen vacancies has a stronger effect on the density and thus elastic properties of stishovite than does the incorporation of hydrogen.

Keywords: Stishovite, elasticity, aluminum, hydrogen, mantle, Brillouin spectroscopy, oxygen vacancies