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Cordierite under hydrostatic compression: Anomalous elastic behavior as a precursor for a pressure-induced phase transition

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Abstract

The high-pressure behavior of cordierite was investigated by means of in situ experiments using piston-cylinder press and diamond-anvil cell. Static compression in diamond-anvil cells was conducted with various penetrating and non-penetrating pressure media (H_2O up to 2 GPa, argon and 4:1-methanol-ethanol up to 7 GPa). The measurement of lattice parameters revealed neither a significant influence on the elasticity nor any indication for effects in analogy to over-hydration within the experimental pressure ranges. Volumetric compression experiments at constant rates up to 1.2 GPa in a piston-cylinder apparatus insinuate subtle irregularities in the low-pressure range at around ~0.35 and ~0.85 GPa. The $\Delta V/V$ contribution related to the anomalous compression behavior in that pressure range is of the order of 5×10^{-4}. The results obtained from single-crystal X-ray diffraction between 10^{-4} and 7 GPa revealed an unexpected and anomalous linear volume decrease, corresponding to $K_{T,298} = 131\pm1$ GPa for the bulk modulus and $K' = -0.4\pm0.3$ for its pressure derivative for a third-order Birch-Murnaghan equation of state. The compressional behavior of the main axis directions is anisotropic with $\beta_a^{-1} \approx \beta_b^{-1} > \beta_c^{-1}$ for an initial pressure regime up to ~3 GPa. At pressures above ~4 GPa, the compression of the *a*- and *b*-axis starts to differ significantly, with the *b*-axis showing elastic softening as indicated by negative values for $\partial(\beta_b^{-1})/\partial P$. The diversification between the *a*- and *b*-axis is also expressed by the pressure-depending increase of the distortion parameter Δ. The pronounced elastic softening in both the *b*-axis and *c*-axis directions $\partial(\beta_b^{-1})/\partial P = -4.3\pm0.9$, $\partial(\beta_c^{-1})/\partial P = -1.2\pm0.8$) are responsible for the apparent linear bulk compression, which indicates the structural instability and precedes a so far not reported ferroelastic phase transition to a triclinic polymorph, following a primitive lattice above the critical transition at ~6.9 GPa.

Keywords: Cordierite, high pressure, compressibility, elastic softening, phase transition