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Strength and Elasticity of Stishovite at Lower Mantle Pressures

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Beamline(s): X17C

Introduction: Stishovite is a prototype for the dense six-coordinated silicates of the Earth's lower mantle. Based on its Vickers hardness (33 GPa) and shear modulus (220 GPa) at ambient conditions, stishovite has been classified as a superhard material. However, there are no direct strength measurements on stishovite at lower mantle pressures. Here we report the results of radial x-ray diffraction measurements on the elasticity, equation of state, and strength of SiO_2 to pressures extending across the stishovite-$CaCl_2$ phase boundary.

Methods and Materials: The stishovite sample was contained in a Be gasket and compressed in a diamond anvil cell under intentionally non-hydrostatic conditions. A gold foil was used as a pressure standard and positional reference. Radial x-ray diffraction experiments were performed in which the focused x-ray beam was directed through the gasket and the diamond cell was rotated so as to vary the angle (ψ) between the diffraction plane normal and the load axis of the cell.

Results: Our data reproduce the wide scatter observed in previous equation of state measurements implying that this scatter can be largely attributed to the effects of diffraction geometry and sample stress state. As expected from lattice strain theory, the *d*-spacings vary linearly with $1-3\cos^2\psi$. The average slope of the *d*-spacing vs. $1-3\cos^2\psi$ relation is directly related to the value of t/G, where t is the differential stress and G is the shear modulus. For stishovite, we find that t/G increases from 0.019(3) to 0.037(3) over the pressure range 15 to 60 GPa. Surprisingly the t/G ratio of stishovite is almost 2 times lower than that of typical four-coordinated silicates such as olivine and ringwoodite. Combining our results with the Reuss bound on the shear modulus from first principles calculations and Landau theory, the differential stress supported by stishovite is 5(1) GPa at pressures below 40 GPa and decreases sharply as the boundary of the stishovite-$CaCl_2$ phase transition is approached. The differential stress then recovers rapidly above the phase transition pressure.

Conclusions: In contrast to its ambient-pressure behavior, we find that the strength of stishovite is relatively low at high pressures and the material undergoes a further dramatic weakening near the transformation to the $CaCl_2$-type structure.

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References:

[1] A. Kavner and T. S. Duffy, *Geophys. Res. Lett.*, **28**, 2691, 2001
[2] J. Chen et al., *Geophys. Res. Lett.*, **25**, 575, 1998.

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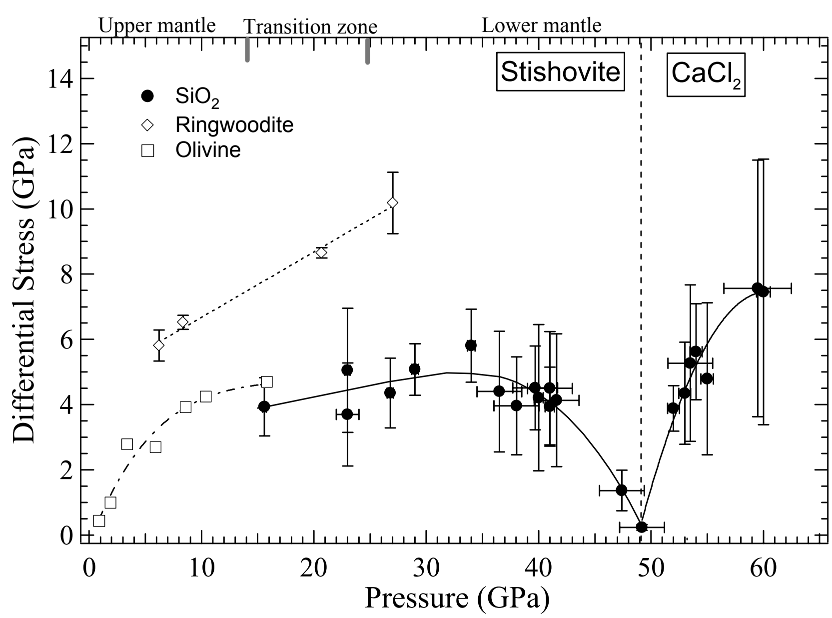

Fig. 1. Differential stress supported by stishovite as a function of pressure. Also shown are results for 4-coordinated silicates ringwoodite [1] and olivine [2].