Single-Crystal Elastic Constants of Forsterite as a Function of Pressure and Temperature Simultaneously to 0.5GPa and 773K: Geophysical Implications for the Upper Mantle

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Abstract

Employing high precision ultrasonic interferometry techniques, we have measured the 9 single-crystal elastic constants Cij of pure forsterite, via 18 velocity modes, as a function of pressure (to 0.5 GPa) and temperature (to 773 K). The values of Cij, (

Part I

Cij/

Part II

P) at ambient temperature, and (

Part III

Cij/

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Part IV

T) at ambient pressure are in good agreement with those reported previously by Kumazawa and Anderson (1969), and Graham and Barsch (1969). We have found that the values of (

Part V

Cij/

Part VI

P) increase with increasing temperature; the temperature effect is more profound for the longitudinal moduli (especially C11) as compared to that for shear moduli. We have also measured, for the first time, the temperature dependence of the pressure derivatives of all the 9 Cij to 573 K, providing the values of (

Part VII

2*Cij/*

Part VIII

P

Part IX

T)T,P. Although the pressure and temperature ranges of our data are limited, the high degree of accuracy of these techniques and the resolution of cross-derivatives allows extremely accurate extrapolation of the properties of olivine throughout its stability field. In particular, measurements of these cross-derivatives of the elastic moduli are deployed to assess the velocity anisotropy of olivine as a function of pressure and temperature, and thus to more accurately calculate the degree of alignment necessary to generate seismically-observed mantle anisotropy as a function of depth in different thermal environments: such constraints on preferred orientation are of fundamental importance in determining the flow field in the upper mantle, and associated with surface tectonics. Furthermore, such data can be utilized to accurately constrain the density of olivine at its highest pressure/temperature equilibrium occurrence in the mantle–directly above its transition to the wadsleyite phase near 410 km depth. Thus, these data, in tandem with accurate wadsleyite data, can illustrate what density jump is anticipated for (Mg,Fe)2SiO4 across this mantle transition.