ABSTRACT

Compressional and shear wave velocities of ringwoodite $\gamma\text{-Mg}_2\text{SiO}_4$ to 12 GPa were measured on a polycrystalline specimen to 12 GPa at room temperature using ultrasonic interferometry techniques. Velocity measurements at ambient conditions yielded $V_p = 9.86(3)$ and $V_s = 5.78(2)$ km/s. Finite strain analysis of the high pressure velocity data yields $K = 185(2)$ GPa, $G = 120(1)$ GPa, $K' = 4.5(2)$, and $G' = 1.5(1)$ for the elastic moduli and their pressure derivatives, respectively. The velocities and elastic moduli at ambient conditions are indistinguishable from aggregate properties of polycrystalline ringwoodite calculated using single crystal elastic constants ($C_{ij}$). Comparison of the current results on pressure derivatives of bulk and shear moduli with previous acoustic data on iron free ringwoodite to 3 GPa and iron bearing sample to 16 GPa indicated that the discrepancy can be explained by the pressure range of the experiments rather than iron content. Current results suggest that ringwoodite and wadsleyite possess very similar pressure dependence in elastic properties to the transition zone depth. In a pyrolite mantle with 1400 °C adiabatic foot temperature, the wadsleyite to ringwoodite phase transition is characterized as a seismic reflector spreading about 20 km in width with a density jump of 2.1% and impedance jumps of 2.4% and 3.1% for P and S waves near 520 km depth, which is consistent with seismic observations in long period data.

INTRODUCTION

Ringwoodite is a high-pressure polymorph of olivine forming at a depth of approximately 520 km in the transition zone of the mantle. In a homogeneous pyrolitic mantle, the physical property change associated with phase transitions from olivine to wadsleyite and wadsleyite to ringwoodite have long been considered responsible for the seismic discontinuities at 410 and 520 km depths (e.g., Ringwood 1975; Katsura and Ito 1989; Bina and Wood 1987; Morishima et al. 1994 and references therein). Unlike the 410 km seismic discontinuity which has been observed worldwide in various studies, universal existence of the 520 km discontinuity is still controversial (e.g., Shearer 1991, 1996; Bock 1994; Benz and Vidale 1993; Flanagan and Shearer 1998; Ryberg et al. 1997). Long-period seismic studies (e.g., Shearer 1990, 1991; Revenaugh and Jordan 1991; Flanagan and Shearer 1998) report a diffuse impedance jump (~3%), but evidence for a 520 km discontinuity in short-period and precursor studies (e.g., Cummins et al. 1992; Benz and Vitale 1993) is less convincing. Although questions about the possibility of the 520 km discontinuity being an artifact in the processing of the long period data of Shearer (1990) were raised by Bock (1994), a later study by Shearer (1996) confirmed the existence of the discontinuity. The existence of 520 km global discontinuity (Shearer 1990, 1996) has also been challenged by the fact that it can be observed only in certain regions but not beneath continental shield (e.g., Ryberg et al. 1997; Gu et al. 1998). In a recent study using precursors to the SS phase, Deuss and Woodhouse (2001) observed splitting of the 520 km discontinuity, suggesting that compositional heterogeneity is responsible for the regional occurrence of single or double discontinuities around this depth.

Laboratory measurements of the elastic properties of wadsleyite and ringwoodite at high pressure and temperature provide insight into Earth’s seismic features since a phase transition occurs at approximately 520 km depth. In the last few years, technical developments have enabled acoustic wave velocity measurements to transition zone pressures using ultrasonic and Brillouin scattering techniques. Application of these techniques to wadsleyite provided valuable data for shear properties which were not available from $P$-, $V$-, $T$- EOS studies (e.g., Li et al. 1996b; Zha et al. 1998). Simultaneous ultrasonic velocity and X-ray diffraction measurements at high pressure and high temperature have also been reported for wadsleyite to 7 GPa and 873 K, yielding direct determination of bulk and shear moduli at pressure and temperature (Li et al. 1998a, 2001). For ringwoodite ($\gamma\text{-Mg}_2\text{SiO}_4$), Rigden et al. (1991) reported ultrasonic measurements to 3 GPa using a polycrystalline sample. Recently, elastic properties of an iron-bearing ringwoodite with composition $\gamma\text{-Mg}_2\text{SiO}_4$ have been measured to 16 GPa using Brillouin scattering (Sinogeikin et al. 2001). However, the pressure derivatives of bulk and shear moduli from these two studies differ by as much as ~20%. The reasons for these differences have been discussed in terms of the effect of iron and the pressure ranges of the different experiments and are further explained in our report.

In this study, velocity data for polycrystalline ringwoodite ($\gamma\text{-Mg}_2\text{SiO}_4$) to 12 GPa at room temperature are presented. The results are compared with previous measurements on iron-free and iron-bearing ringwoodite. Using previous data on wadsleyite, the physical property change across the phase transition from wadsleyite to ringwoodite and their implications for the 520 km discontinuity will be discussed.

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