In Situ Determination of the Phase Boundary between γ-Mg_2SiO_4 and $MgSiO_3$ Perovskite + MgO

S.-H. Shim,[1] T. S. Duffy,[1] G. Shen[2]

[1] *Department of Geosciences, Princeton University, Princeton, NJ, U.S.A.*

[2] *GSECARS, The University of Chicago, Chicago, IL, U.S.A.*

Introduction

The prominent seismic discontinuity at 660-km depth is a major structural feature that separates the Earth's upper and lower mantle. Understanding this discontinuity is essential for constraining the evolution, composition, and dynamics of the planet's interior. Based on laboratory quench experiments,[1] it has been proposed that the phase transformation between γ-$(Mg.Fe)_2SiO_4$ and $(Mg,Fe)SiO_3$ perovskite + (Mg,Fe)O is primarily responsible for this discontinuity. However, recently the first *in situ* determination using a multianvil press and synchrotron x-ray diffraction suggested that this phase transition may occur at a much shallower depth (~610 km) at conditions of the Earth's mantle.[2] To better understand this discontinuity, we have carried out an *in situ* x-ray diffraction study using the laser-heated diamond anvil cell.

Methods and Materials

We used synthetic Mg_2SiO_4 as a starting material. For laser heating and pressure measurement,[3] platinum was mixed with the powdered starting material. A thin foil of sample mixture was loaded in a diamond cell with argon as a pressure-transmitting medium. In situ laser heating with energy-dispersive x-ray diffraction measurements were performed at the GeoSoilEnviroCARS sector of the Advanced Photon Source. Temperatures were measured by fitting the measured thermal radiation spectra, which are corrected for system response, to the Planck equation. A total of nine heating runs were performed at 18-30 GPa and 1200-2200K.

Results

Heating runs (~ 30 minutes duration) were carried out at conditions near the expected phase boundary (20-30 GPa, 1400-2000K). Experiments were performed in both the forward and reverse directions by using starting assemblages that were first transformed either entirely to rinwoodite (γ phase) below 20 GPa or to the perovskite-MgO mixture at pressures above 30 GPa. We were readily able to observe the transformation in both the forward and reverse directions, although interpretation is complicated by kinetics, preferred orientation, and P-T fluctuations during heating. Our x-ray diffraction measurements show that the phase transition from the γ phase to perovskite+periclase occurs at 23.7±1.1 GPa at 1800K (Fig. 1). This was also confirmed by the experiment for perovskite+MgO → γ performed during decompression.

Discussion

Our result shows that the phase boundary between γ-Mg_2SiO_4 and $MgSiO_3$ perovskite + MgO occurs at conditions close to 660-km depth at expected mantle temperatures (~1600-2000K). The difference between the phase boundary from this study and Irifune et al.[2] is 2.6 GPa. Several factors must be investigated to explain this discrepancy including inaccuracies of internal pressure scales (gold, platinum, and periclase), pressure dependence of emf in thermocouples, and deviatoric stress effects.[4]

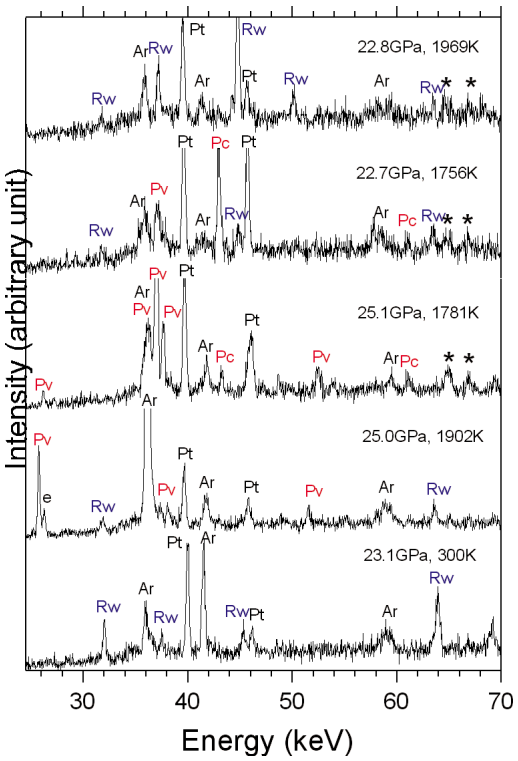

*FIG. 1. Representative x-ray diffraction patterns at the indicated P–T conditions. Peak identifications are: Rw: ringwoodite, Pv: perovskite, Pc: periclase, Pt: platinum, Ar: argon, *: platinum fluorescence, e: detector escape peak.*

Acknowledgments

We thank S. Speziale and the GSECARS staff for experimental assistance. Use of the Advanced Photon Source was supported by the U.S. Department of Energy, Office of Science, Office of Basic Energy Sciences, under Contract No. W-31-109-ENG-38.

References

[1] E. Ito and E. Takahashi, J. Geophys. Res. **94**, 10637–10646 (1989).

[2] T. Irifune et al., Science **279**, 1698–1700 (1998)

[3] N. C. Holmes et al., J. Appl. Phys. **66**, 2962–2967 (1989).

[4] S.-H. Shim et al. Nature, in press.