Stability of $MgSiO_3$ Perovskite to 107 GPa and 2500K

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Introduction

The phase relationships and crystal structures of minerals of the Earth's lower mantle are important for understanding seismic observations of the deep mantle and their geochemical and geodynamic implications. The stability of (Mg, Fe)SiO3 perovskite has been the subject of great controversy over the last decade. The stability of this material was confirmed on temperature-quenched samples,[1] but several *in situ* x-ray diffraction measurements at high P-T have reported a decomposition of $MgSiO_3$ perovskite to MgO + SiO_2.[2,3] However, other recent studies have reported that this material was stable to 100 GPa and 2000K.[4-6] The origin of the discrepancy between these results remains controversial. The primary issues include the homogeneity of heating, stress conditions, transformation kinetics and the possibility of chemical reactions.

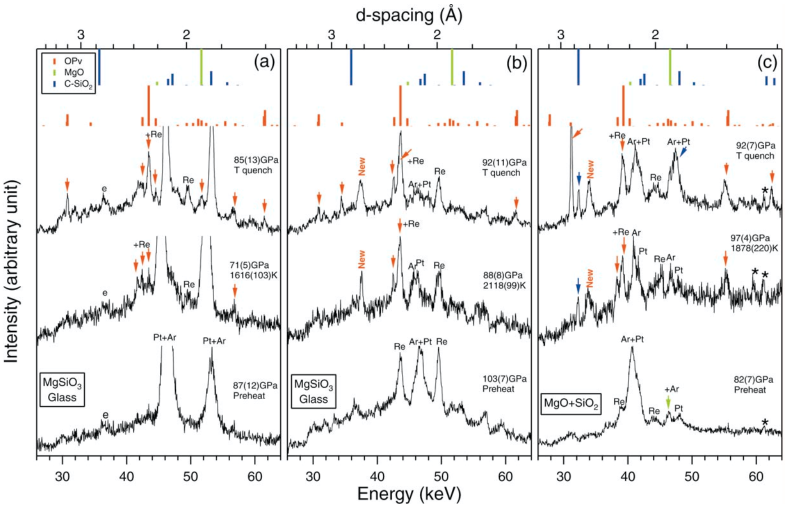

*FIG. 1. Representative x-ray diffraction patterns at the indicated P-T conditions. Calculated patterns for orthorhombic Pbnm perovskite (red) using the structural parameters measured at 79.7 GPa and 1681K (ref. 5), periclase (green), and $CaCl_2$-type SiO_2 (blue) are shown at the top. Peak identification is presented for each diffraction line (red arrows: $MgSiO_3$ perovskite, blue arrows: $CaCl_2$ type SiO_2, green arrows: periclase, New: possible new perovskite line, Pt: platinum, Ar: argon, Re: rhenium, *: x-ray fluorescence, e: escape peak). (A) $MgSiO_3$ glass → $MgSiO_3$ perovskite (Pbnm) below 88 GPa. (B) $MgSiO_3$ glass → $MgSiO_3$ perovskite plus new line. (C) $MgO+SiO_2$ → $MgSiO_3$ perovskite plus new line.*

Methods and Materials

We used three different starting materials, $(Mg,Fe)SiO_3$ enstatite, $MgSiO_3$ glass, and an $MgO+SiO_2$ mixture. Platinum powder was mixed with the starting material for use as an internal pressure calibrant[7] and to promote laser absorption. Argon was loaded as an insulation and pressure medium. We used a symmetric diamond anvil cell with 100-mm beveled culets. Energy dispersive x-ray diffraction measurements were performed before, during, and after the laser heating at pressures of 40-107 GPa and temperatures up to ~2500K. Thermal radiation spectra were also measured using an imaging spectrometer and a CCD detector for temperature determination.

Results

As shown in Fig. 1, the observed x-ray diffraction patterns show good agreement with that of $MgSiO_3$ perovskite. This was consistently observed throughout our experiments and for three different starting materials. Also the synthesis of $MgSiO_3$ perovskite was directly confirmed at high pressure and temperature from $MgSiO_3$ glass and the MgO + SiO_2 mixture. These observations confirm the stability of MgSiO3 perovskite to 2300-km depth of the Earth's mantle. Above 88 GPa, we were also able to observe the appearance of a new line at 2.62 Å. Calculations show that this is not diffraction from *Pbnm* perovskite, $CaCl_2$-type or α-PbO_2 type SiO_2, MgO, Ar, and Pt. Instead, it can be indexed as (012), which is a forbidden diffraction line in *Pbnm* perovskite. We found that this line could be explained by $P2_1/m$, *Pmmn*, and $P4_2/m$ perovskites. However, the possibility that the new peak is due to an unexpected reaction product or highly oriented impurity phase cannot be ruled out.

Discussion

The primary result of this study is that $MgSiO_3$ perovskite is stable to conditions corresponding to 2300-km depth in the Earth's mantle. However, the possibility of additional transformation within the perovskite system warrants further investigation.

Acknowledgments

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References

[1] E. Knittle and R. Jeanloz, Science **235**, 668 (1987).
[2] C. Meade et al., Science **268**, 1743 (1995).
[3] S. K. Saxena et al., Science **274**, 1357 (1996).
[4] G. Serghiou et al., Science **280**, 2093 (1998).
[5] G. Fiquet et al., Geophys. Res. Lett. **27**, 21 (2000).
[6] D. Andrault, J. Geophys. Res. **106**, 2079 (2001).
[7] N. C. Holmes et al., J. Appl. Phys. **66**, 2962 (1989).