

## Stability field of the high-temperature orthorhombic phase in the enstatite-diopside system

SHUGO OHI,<sup>1,2,\*</sup> AKIRA MIYAKE,<sup>2</sup> AND MASATOMO YASHIMA<sup>3</sup>

<sup>1</sup>Department of Earth and Space Science, Graduate School of Science, Osaka University, Toyonaka 560-0043, Japan

<sup>2</sup>Department of Geology and Mineralogy, Division of Earth and Planetary Sciences, Graduate School of Science, Kyoto University, Kyoto 606-8502, Japan

<sup>3</sup>Department of Materials Science and Engineering, Interdisciplinary Graduate School of Science and Engineering, Tokyo Institute of Technology, Yokohama 226-8502, Japan

### ABSTRACT

This research investigated the phase transition between low- and high-temperature orthopyroxenes with composition  $(\text{Ca}_{0.06}\text{Mg}_{1.94})\text{Si}_2\text{O}_6$  using differential scanning calorimetry experiments and in situ high-temperature X-ray diffraction. The transition enthalpy, temperature, volume change, and slope were estimated to be 6.2 kJ/mol, 1170 °C, 10.25 Å<sup>3</sup>/unit cell, and 0.0056 GPa/°C, respectively. The phase boundary between low- and high-temperature orthopyroxene was defined as  $P$  (GPa) = 0.0056  $T$  (°C) – 6.55. This relationship shows that the invariant point for four-phase equilibria (protoenstatite + high-temperature orthopyroxene + pigeonite + diopside) is approximately 1240–1280 °C and 0.1–0.2 GPa, rather than the equivalent system involving low-temperature orthopyroxene as described in previous studies. We developed phase diagrams for  $\text{Mg}_2\text{Si}_2\text{O}_6$  and the  $\text{Mg}_2\text{Si}_2\text{O}_6$ - $\text{CaMgSi}_2\text{O}_6$  system taking into account the results of previous synthetic experiments and the phase boundary that we determined between low- and high-temperature orthopyroxene. The developed phase diagrams for  $\text{Mg}_2\text{Si}_2\text{O}_6$  showed that high-temperature orthoenstatite is more stable than protoenstatite at pressure above ~0.8 GPa, and that the boundary between high-temperature orthoenstatite and protoenstatite has a gentle negative slope. As pressure is increased from 1 atm to about 0.2 GPa, the lower temperature limit of stability of high-temperature orthopyroxene decreases from ~1370 to ~1200 °C. Above 0.9 GPa, the stability field of protoenstatite disappears and high-temperature Ca-free orthopyroxene is stable. On the basis of these results, it is suggested that further high-resolution analyses of the thermodynamics of the enstatite-diopside system at high temperatures and high pressures are required.

**Keywords:** High-temperature, orthopyroxene, differential scanning calorimetry, X-ray powder diffraction, isosymmetric phase transition, phase diagram, enstatite-diopside system