Sound velocity measurements of $MgSiO_3$ majorite and akimotoite at high pressure and high temperature with simultaneous in situ X-ray diffraction and ultrasonic study

CHUNYIN ZHOU (周春銀)

Submitted to Graduate School of Science and Engineering, Ehime University in Partial Fulfillment of the Requirements for the Degree of Doctor of Science

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by

CHUNYIN ZHOU (周春銀)

Supervisor: Prof. **Tetsuo Irifune (入舩 徹男)**

Director of Geodynamics Research Center,

Ehime University, Matsuyama, Japan

CERTIFICATE

This is to certify that the work in this thesis entitled "**Sound velocity measurements of $MgSiO_3$ majorite and akimotoite at high pressure and high temperature with simultaneous in situ X-ray diffraction and ultrasonic study**", is carried out by **Chunyin Zhou** at **Geodynamics Research Center** (GRC), Ehime University, Japan under supervisions of **Prof. Tetsuo Irifune**, Director of GRC, Ehime University, Matsuyama, Japan for partial fulfillment of the degree of **Doctor of Science** in **High Pressure Mineral Physics**. The thesis is prepared in accordance to the rules and regulations of the **Graduate School of Science and Engineering, Ehime University**. No part of this dissertation has been submitted anywhere for award of any degree or otherwise to the best of my knowledge.

Professor & Director: Oga Mitao

Graduate School of Science and Engineering, Ehime University, Japan 790-8577

(Official Seal)

Graduate School of Science and Engineering, Ehime University, Japan 790-8577

Abstract

High pressure polymorphs of $MgSiO_3$ are abundant constituents in the Earth's mantle and their elastic properties at high pressure and high temperature are of great significance to address the mineralogy and seismic profile of the mantle. Using the newly developed ultrasonic interferometry (UI) technique combined with in situ X-ray diffraction and radiography in a multianvil at the synchrotron beamline BL04B1, Spring-8, the author measured the elastic velocities of polycrystalline $MgSiO_3$ majorite and akimotoite up to the P-T conditions of the mantle transition zone. In this thesis, the author has discussed the ultrasonic experimental results and their implications.

Elastic wave velocities of $MgSiO_3$ majorite garnet polycrystalline have been measured at P-T conditions of 8-19 GPa and 300-900 K by ultrasonic interferometry method. Both compressional and shear wave velocities, as well as bulk and shear moduli, increase with increasing pressure but decrease with increasing temperature. A two-dimensional (P-T) linear fitting to the present data yields: K_S = 162.1(5) GPa, $\partial K_S/\partial P$ = 4.20(4), $\partial K_S/\partial T$ = -0.0167(5) GPa/K, G_0 = 86.2(2) GPa, $\partial G/\partial P$ = 1.03(1), $\partial G/\partial T$ = -0.0084(2) GPa/K. The derived elastic moduli at ambient conditions here are slightly lower than previous studies, while we provide new data on the temperature dependences. Combined with previous available experimental data, it is difficult to make a conclusion on if the elastic moduli have linear relations to the composition along the majorite-pyrope ($Mg_4Si_4O_{12}$-$Mg_3Al_2Si_3O_{12}$) solution joints. And the velocities of $MgSiO_3$ majorite are lower than those of grossular ($Ca_3Al_2Si_3O_{12}$) and pyrope end members, and much lower

than the seismological models in the mantle transition zone. Thus, a majorite-rich garnet bearing mineralogical model for the mantle transition zone will produce lower velocities in the mantle transition zone.

Subsequently, elastic wave velocities of $MgSiO_3$ akimotoite polycrystalline samples have been measured at pressures up to 25.7 GPa and temperatures to 1500 K by a combination of in situ X-ray diffraction and ultrasonic interferometry techniques in a large volume Kawai-type multianvil apparatus (KMA). The elastic moduli of akimotoite and their pressure and temperature dependences are determined by a 2D linear fitting analysis of the present data, yielding: K_S = 219.4(7) GPa, $\partial K_S/\partial P$ = 4.62(3), $\partial K_S/\partial T$ = -0.0228(4) GPa/K, G_0 = 132.1(7) GPa, $\partial G/\partial P$ = 1.63(4), $\partial G/\partial T$ = -0.0225(4) GPa/K. The bulk and shear moduli at ambient conditions are generally consistent with the result of a previous Brillouin spectroscopy study. However, significant nonlinear behaviors of the elastic moduli were observed at higher temperatures, indicating that the velocities derived from the linear fitting analysis are overestimated for the actual mantle conditions. Using the present new experimental data, we compared the elastic velocities of various high-pressure forms of $MgSiO_3$ under the mantle conditions. The results demonstrate a large velocity contrast between akimotoite and perovskite. Therefore, Ak-Pv transition in a harzburgite layer of subducted slabs may produce a discontinuity above 660 km, which may be relevant to the complex seismic structures near the bottom of the mantle transition zone.

The effects of other minor component, such as Fe, Al, and H_2O, on the elastic properties of majorite, akimotoite and perovskite should be carefully demonstrated by further studies in the future.

Keywords: $MgSiO_3$; majorite garnet; akimotoite; ultrasonic interferometry; elastic velocity; in situ X-ray diffraction; nonlinear; mantle transition zone.