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Elastic properties and structures of pyrope glass under high pressures

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ABSTRACT

X-ray diffraction analysis and ultrasonic measurements of a glass with the pyrope composition were conducted to determine its structural and elastic properties at pressures from 1 atm to 12.9 GPa. Our results indicate that its structural evolution is closely related to changes in the compression wave velocity (V_P), shear wave velocity (V_S), and Poisson ratio. We observed three modes of pyrope glass compression. Moderate shrinkage in the intermediate-range ordered structure occurred at pressures below 6 GPa. Significant shrinkage in the intermediate-range ordering was observed at pressures between 6 and 9 GPa. We observed changes in the short-range ordered structure at pressures above 9 GPa, which were associated with an increase in the coordination number of tetrahedral cations. The absolute values of V_P and V_S in pyrope glass are similar to those in magnesium-bearing silicate glasses with enstatite and diopside compositions. However, the velocities are higher than those observed in sodium aluminum silicate glasses with jadeite and albite compositions. This indicates that the velocities are governed by the initial density of a glass, which is determined by its chemical composition. In terms of pressure, the velocity minimum in pyrope glass occurs at ~5 GPa, which is similar to the velocity minima in fully polymerized glasses, such as jadeite and albite. The degree of polymerization in pyrope glass is intermediate, and it has a relatively polymerized network. A drastic increase in velocity was observed when the pyrope glass was subjected to pressures above 7–8 GPa, and the velocity exceeded that observed in silicate glasses. Densification phenomenon, such as an increase in the Al coordination number, was efficiently promoted. This was because the cationic field strength of Mg^{2+} exceeds those of typical non-network forming cations. Magnesium cations may have an important role in controlling the behavior of silicate glass, and partially melted mantle becomes enriched with Mg under pressure. Studying Mg-bearing aluminosilicate glasses can thus help us to better understand the behavior of magma deep in the interior of the Earth.

Keywords: Pyrope glass, elastic wave velocity, structure, high pressure; Physics and Chemistry of Earth's Deep Mantle and Core