Report for the Joint Use/Research of the Institute for Planetary Materials, Okayama University for FY2024

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Category: ☐International Joint Research ☑General Joint Research ☐Joint Use of Facility ☐Workshop

Name of the research project: Effect of iron content on the sound velocities of ferropericlase under planetary mantle conditions.

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Research report:

Ferropericlase is believed to be a major constituent of planetary interiors. In the Earth's lower mantle, assuming a pyrolitic composition, it accounts for approximately 20% of the volume, with the remaining 80% composed primarily of bridgmanite. Petrological studies have reported that the chemical composition of lower-mantle ferropericlase, expressed in terms of the molar fraction of FeO (X_{FeO}), ranges from 0.08 to 0.18 (Hirose, 2002; Irifune, 1994; Ishii et al., 2011, 2018; Kuwahara et al., 2018). In contrast, ferropericlase inclusions found in super-deep diamonds exhibit X_{FeO} values as high as 0.85 (e.g., Walter et al., 2022), suggesting that much more variable compositions may be relevant to the Earth's deep interior.

The compositional variability of ferropericlase, particularly in its iron content, is also significant for other terrestrial planets. For example, recent studies on the fractional crystallization of the Martian magma ocean predict the formation of a thermochemical boundary layer at the base of the Martian mantle, potentially composed of iron-rich ferropericlase and garnet (Zeff and Williams, 2019). Despite its importance, only a few

studies have investigated the effect of iron incorporation on the sound velocities of periclase at high pressure. Consequently, elasticity data on ferropericlase remain limited to a narrow range of compositions and pressures, typically up to 9 GPa (Jackson et al., 1978; Kung et al., 2002). Such data are crucial for constraining the composition (e.g., X_{FeO}) of periclase in planetary interiors through direct comparisons between laboratory measurements and seismological observations. This fundamental information provides valuable insight not only into the bulk composition of the Earth's lower mantle but also into the dynamics and thermal evolution of other terrestrial planets, as the presence of iron can significantly influence the physical properties of ferropericlase (e.g., Zhang et al., 2023).

In this study, we plan to investigate the sound velocities (V_P and V_S) of ferropericlase with different iron content (X_{Fe} = 0.03, 0.05, 0.10, 0.20, and 0.30) under high-pressure, by means of ultrasonic interferometry measurements in the large volume press apparatus. We have synthesized ferropericlase with several different iron contents (X_{Fe} = 0.05, 0.10, 0.20 and 0.30) in a gas mixing furnace and ground the recovered pellets to fine-grain powder. Some of the powder was used as a starting material for sintering experiments in a piston-cylinder apparatus. In this fiscal year, we have successfully gotten two well-sintered ferropericlase aggregates with 5 and 20 mol% Fe, respectively. These samples will be used for in-situ sound velocity measurements at BL04B, SPring8, during our beamtime in the middle of July. We expect these samples to help obtain high-quality data.