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

5/18/2025

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

Name of the research project: Experiment constraints on thermal properties of mantle transition zone and subducting slabs: investigation of slab dynamics and mechanism of deep-focus earthquake

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Research report:

Limited by the inaccessibility of Earth's interiors, our knowledge of internal dynamics relies on the geophysical observations and models with certain physical properties of planetary materials determined by laboratory experiments. Although seismic observations provide plenty of information on the interior structure, without crucial constraints such as slab temperature profile, nature phenomena like deep-focus earthquakes and slab stagnation still remain enduring unknowns (Fig. 1). Thermal conductivity controls the magnitude of conductive heat transfer in subducting slabs and mantle transition zone (MTZ), determining the temperature distributions and thermo-chemical evolution of these regions. Accurate thermal conductivity values of constitute materials of slabs and MTZ are therefore essential for realistic models of slab dynamics and MTZ structure.

Wadsleyite (wd) and ringwoodite (rw) are the main phases in the MTZ and can appear in metastable olivine wedge of subducting slabs at depths deeper than 410 km, while majoritic (maj) garnet constitutes almost the entirety of the crustal portion of the subducting slab at the depth of the MTZ. Akimotoite (ak) is believed to be formed in the cold subducting slab at the bottom of the MTZ (Fig. 2). Thermal properties of these major phases definitively govern the thermal state and slab dynamics, thus accounting for the slab stagnation in MTZ and the generation of deep-focus earthquakes.

In this fiscal year, dry ringwoodite with varying Fe contents, specifically $(Mg_{0.9}Fe_{0.1})_2SiO_4$ and $(Mg_{0.7}Fe_{0.3})_2SiO_4$, was synthesized at 20 GPa and 1775 K using a Kawai-type multi-anvil apparatus. The thermal conductivity and thermal diffusivity of Fe-bearing ringwoodite were determined simultaneously by combining the multi-anvil high-pressure experimental technique with the pulse heating method, up to 20 GPa and 1100 K. The pressure and temperature dependencies of thermal conductivity for ringwoodite with different iron contents were obtained, as shown in Fig.1 and Fig. 2. The experimental results show that $(Mg_{0.9}Fe_{0.1})_2SiO_4$ ringwoodite exhibits higher thermal conductivity values than previous studies, which may suggest a negative effect of water on the thermal conductivity of ringwoodite. $(Mg_{0.7}Fe_{0.3})_2SiO_4$ ringwoodite has a thermal conductivity of approximately half that of $(Mg_{0.9}Fe_{0.1})_2SiO_4$ under the same P-T conditions, indicating a strong iron effect on the thermal properties of ringwoodite. The contrast in thermal conductivity between ringwoodite and olivine is much larger in Earth's mantle compared to Mars, suggesting that the thermal evolution of these two terrestrial planets may differ.

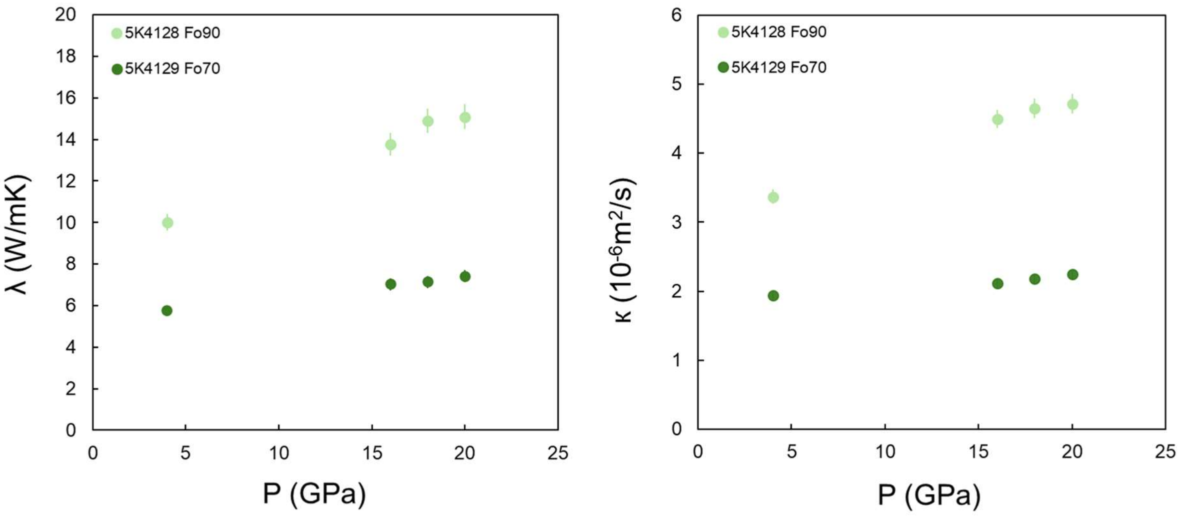

Fig. 1 Pressure dependence of thermal conductivity and thermal diffusivity of dry Fo90 ringwoodite and Fo70 ringwoodite

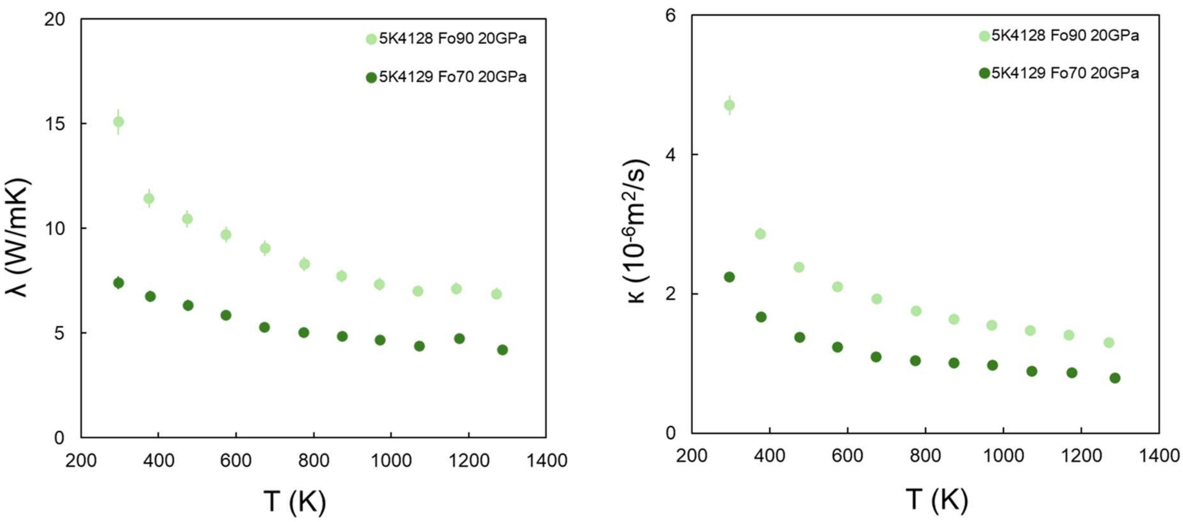

Fig. 2 Temperature dependence of thermal conductivity and thermal diffusivity of dry Fo90 ringwoodite and Fo70 ringwoodite