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

2022 fiscal year second call

01/19/2023

Category: International Joint Research

Name of the research project: The relative strength of MORB and pyrolite at the upper/lower mantle boundary

Principal applicant: Fang Xu

Affiliated institution and department: Department of Earth Sciences, University College London

Collaborator Name: David Dobson

Affiliated institution and department: Department of Earth Sciences, University College London

Collaborator Name: Daisuke Yamazaki

Affiliated institution and department: Institute for Planetary Materials, Okayama University

Research report:

Subducted oceanic lithosphere is composed of two chemically distinct layers, namely mid-ocean-ridge basalt (MORB) and depleted peridotite layers (harzburgite, Hbg). The fate of MORB and Hbg layer has important implications for: (1) complex slab behavior and mantle convection around 660-1000 km depth; (2) the production of seismic scatterers in the lower mantle; (3) the source of enriched OIB at the core-mantle boundary and the base of the transition zone and (4) the composition and origin of enriched components in OIB magmas. The strength (viscosity) contrast of the MORB layer with the slab core and surrounding mantle plays an important role in controlling the behavior of MORB layer, e.g., a moderately stronger (0-2 orders) MORB layer is favored for the delamination of MORB atop 660 km (Karato, PEPI 99, 103-111, 1997). However, little is known about the viscosity of deep subducted slab and its components. Therefore, we propose to measure the relative strength of MORB and Hbg under the range of pressure and temperature conditions of the subducting slab across the mantle transition zone to ~800 km depth.

We planned to conduct deformation experiments on MORB and Hbg two layered samples, i.e., pre-synthesized ringwoodite (Rw)/post-spinel (PS) sample against MORB composition, which is dominated by majorite garnet and stishovite synthesized at the same pressure with Rw/PS, with D111 apparatus. The strain contrast enables a direct measurement of the relative strength of MORB and Hbg hence to imply the behavior of slab at lower mantle transition zone and top lower mantle. Before and after the deformation experiments, the samples are analyzed by XRD, SEM and EDS carefully for phase identification, structure, and composition.

During the visit, firstly, three testing experiments were conducted to calibrate 8/3 cell assembly in D111 apparatus. In total four deformation experiments on Rw and MORB two layered samples were conducted at 1200-1600 ℃. We found that the Rw and MORB shows very small strain contrast, i.e., smaller than a factor of two, which indicates a comparable viscosity of Rw and MORB. Before the good load for deformation of Rw was found, three Rw samples partially transformed to post-spinel mixture (PS) in deformation experiment, thus the viscosity contrast of PS+Rw and MORB were obtained at 1400 ℃. It turns out that the PS+Rw samples is much softer than MORB sample, up to one order of difference. It strongly suggests that the PS just after the phase transition, which shows eutectoid texture of ferropericlase and bridgmanite with grain size of ~200 nm, might be much softer than majorite garnet. We therefore pre-synthesized PS sample with eutectoid texture and conducted the deformation experiment at 1400 ℃; a large strain in PS and large strain contrast with MORB sample was observed.

The results of the joint use this time, plus our previous result on wadsleyite and PS indicate that highly likely that MORB and Hbg layer have comparable strength through transition zone to lower mantle except extreme softening of PS at the depth just below PS phase transition, which is ~660 km. It will give a significant implication for slab delamination and MORB stagnation at top lower mantle. More experiments are needed to further study the details. We will propose the next term joint use with IPM on the future study on this project.