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Effect of liquid Fe-S on elastic wave velocity of olivine aggregate investigated by ultrasonic measurement and X-ray microtomography analysis

YOSHIO KONO[1], HIDEHARU KUWAHARA[1], STEEVE GREAUX[1], MARK RIVERS[2], YANBIN WANG[3], YUJI HIGO[4], KEISUKE MITSU[1] AND NOZOMI KONDO[1]

[1]Ehime University
[2]University of Chicago
[3]The University of Chicago
[4]Japan Synchrotron Radiation Research Institute

Presenting Author: kono.yoshio.rj@ehime-u.ac.jp

Recent studies of the Apollo seismic data revealed the existence of a seismic low velocity zone (LVZ) at the base of the lunar mantle, suggesting the presence of molten materials at the base of the lunar mantle. Liquid Fe-S is considered as a possible candidate of the cause of the LVZ. However, an unresolved issue is whether liquid Fe-S can produce strong reduction of seismic wave velocities to match that of the LVZ. It has been reported that liquid Fe-S forms high dihedral angles with olivine at the pressure and temperature conditions of the lunar mantle. Theoretical calculations show that high dihedral angle liquid has only small effect on seismic wave velocity, hence it may be difficult to explain the LVZ. However, this discussion has not been verified in experiment.

Here we conducted direct elastic wave velocity measurements on liquid Fe-S-bearing olivine aggregates at high pressure and high temperature conditions, and characterized microstructures using 3D X-ray microtomography. We report strong reduction of the elastic wave velocities in the presence of liquid Fe-S. The effects of liquid Fe-S in olivine aggregates are much more pronounced than the theoretical estimation based on the high dihedral angle of liquid Fe-S in olivine aggregate observed in previous microstructural analysis of polished sample cross sections. Three-dimensional X-ray microtomography analysis reveals that the geometry of liquid Fe-S strongly depends on the size, with larger liquid Fe-S blobs having low aspect ratios, which may predominantly affect elastic wave velocity. Our results suggest that the LVZ at the base of the lunar mantle can be explained by the presence of 4.3-5.0 vol.% liquid Fe-S.