Effect of Spin transition of iron in physical properties of hydrous phase δ-(Al,Fe)OOH under the lower mantle conditions

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Recent experimental evidence indicated that the Earth’s transition zone contains significant amount of water at least locally. Subduction of the slabs into the lower mantle can transport water further into the lower mantle. One of the most important carrier of water into the lower mantle is hydrous phase δ. Our works on the stability of this phase revealed that it coexists with bridgmanite in the lower mantle [1, 2]. Therefore, existence of δ-phase could potentially make the significant effect on dynamics of the lower mantle.

Our experimental works of time domain synchrotron Mossbauer spectroscopy revealed that δ-(Fe,Al)OOH undergoes a HS–LS transition at the pressure range of 32–45 GPa. Our compression experiments of the phase showed that the volume collapse due to a transition from high-spin to low-spin states in the Fe^{3+} ions occurs at pressures of 32–40 GPa [3]. These observations revealed that there is reduction in the bulk sound velocity associated with the spin-transition at the top of the lower mantle.

In order to clarify the effect of the spin transition on physical properties of δ-(Fe,Al)OOH, we have measured the thermal conductivity of this phase at room temperature and high pressure exceeding 100 GPa. The measurement was conducted by using TDTR (Time Domain Thermoreflectance method) combined with a diamond anvil cell [4]. The thermal conductivity varies drastically by twofold to threefold across the spin transition of iron, resulting in the thermal conductivity of δ-(Al,Fe)OOH-rich crustal material larger than that of the surrounding pyrolitic mantle, which may in turn enhance the heat transfer between the slab and its surroundings at the top of the lower mantle. Whereas, the low-spin Fe^{3+} bearing δ-phase has an exceptionally low thermal conductivity at the lowermost mantle. Such a drastic variation of thermal conductivity would induce temperature anomaly within the slab promoting local heterogeneous density and buoyancy distribution at the base of the lower mantle.

References: [1] Ohira et al. (2014) Earth Planet. Sci. Lett., 401: 12–17, [2] Ohtani et al. (2018) Jour. Asian Earth Sci. 2018, [3] Ohira et al. (2019) Am. Mineral., 104(9), 1273–1284, [4] Hsieh et al. (2020), GRL, 47, e2020GL087036.

Keywords: Spin transition of iron, Hydrous δ-(Al,Fe)OOH, Thermal conductivity, Lower mantle

