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Laboratory-based electrical conductivity profile of the mantle transition zone

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Recent laboratory electrical conductivity measurements of the main mantle constituent minerals have refined our understanding of the effect of water and iron content on electrical conductivity. However, there have remained inconsistency of conductivity data between different laboratories, especially effect of water on the conductivity (proton conduction). Karato and Dai (2009) claimed that our group's data, mostly based on low frequency measurements, used incorrect sample conductivity values, because their impedance spectroscopy for wet wadsleyite measured at high temperatures showed an additional tail at low frequencies. To calrify a cause of this discrepancy, we performed the impedance spectroscopic measurements for wadsleyite in a wide frequency range at low temperatures (< 1000 K) to minimize dehydration of samples. The results are quite consisitent with ours measured at low frequencies, and did not show a large contribution of small amount of water to the conductivity and an additional tail at low frequencies due to the electrode reaction. It is concluded that the conductivity measurement at high temperatures (> 1000 K) leads to higher conductivity due to the grain boundary water generated by dehydration of sample.

Next we consider the electrical conductivity structure of the mantle transition zone based on our results. The electrical conductivity of the Earth's mantle is controlled by the coexistence of multiple mineral phases. Using these conductivity data of mantle minerals and geotherm models, the laboratory-based conductivity-depth profiles have been constructed of a 200 to 800 km depth range across the mantle transition zone. These profiles are based on mixing models of composite materials, which assume a pyrolitic composition, and they are a function of water content in main constituent minerals. The calculated conductivity values increase from 10-2 S/m at 200 km depth to 100 S/m at 800 km depth. Considering the conductivity change due to the phase change only, our model predicts similar values between olivine and wadsleyite, but they differ up to nearly one order of magnitude between wadesleyite and ringwoodite. In other words, if a conductivity jump accompanies the 410 km seismic discontinuity, it will not be due to the phase change but to a secondary effect, such as difference in water content. Instead, a notable conductivity jump appears at a depth of 520 km in the wadsleyite-ringwoodite transition with or without water. The present conductivity-depth profile in the transition zone agrees with that obtained from the geophysical observations beneath the Pacific Ocean in the case of the dry mantle transition zone. The absolute conductivity values obtained from the conductivity profiles beneath the Philippine Sea, where stagnant slab exists, are too high to be explained by the dry pyrolite model, especially in the stability field of wadsleyite. Presence of water in the transition zone minerals is required to explain such high conductivity.

Keywords: electrical conductivity, mantle transition zone, water, olivine, wadsleyite, ringwoodite