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Electrical conductivity of stishovite: effects of Al2O3 and water

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Stishovite is one of the major constituent minerals in subducted oceanic crust. At pressures above 25 GPa, the post-garnet assembly transformed from garnetite originated from eclogite contains up to 25 vol.% stishovite. On the other hand, if Archean continental crust mainly consisteing of tonalite-trondhjemite-granodiorite (TTG) was destructed and subucted into the deep mantle, its assembly contains more than 80 vol.% stishovite. In this case, stishovite should be considered as a main controling phase for the electrical conductivity structure of the mantle. Electrical conductivity of stishovite is expected to be very low because migration of Si and O vacancies is quite slow even high temperature. However, electrical conductivity of stishovite may drastically increase because of their fast mobility as a charge carrier when stishovite crystals contain small amounts of Al and H.

In the present study, effects of Al and H components on electrical conductivity of stishovite was investigated to consider as a cause of the high conductivity anomaly observed in the mantle transition zone. The starting materials were prepared from SiO2 powder with various amounts of Al(OH)3. Stishovite aggregates were synthesized at 12 GPa and 1673 K. Chemical composition of the run products was SiO2 with various amounts of Al2O3 (0, 1, 5 wt.%) and water. The electrical conductivity measurements were performed at 12 GPa and various temperature conditions to detect effect of water. Relatively dry conditions were accomplished by annealing at 1900 K, proton conduction can be detected under relatively lower temperature conditions less than 1100 K. The conductivity of stishovite increases with increasing H2O and Al2O3 contents. This trend implies that the charge carrier in stishovite is probably interstitial alkali ion in association with substitutional Al in Si site. At low temperatures, the Al-related defect occupied by proton in Si site could be a main charge carrier. Because activation enthalpy for proton conduction is lower than that for Al3+-M+ pair and its dissociation products, proton conduction could be dominant conduction mechanism below 1100 K.

Electrical conductivity of Al-bearing stishovite (more than 1 wt.% Al2O3) is more than one order of magnitude higher than those of wadsleyite and ringwoodite. The high conductivity values observed in the mantle transition zone can be explained by a presence of aluminous stishovite derived from subduction of Archean continental crust.

Keywords: stishovite, electrical conductivity, mantle transition zone