

## The effect of water on the electrical conductivity of olivine aggregates

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Olivine is thought to be the most abundant mineral of the upper mantle and can store water as the hydroxyl group together with intrinsic point defects in their structure. Even if the water concentration is very low the presence of hydrogen in olivine significantly affects a variety of physical and chemical properties such as plastic deformation, melting temperature and seismic velocity. Therefore, estimating the water content of the upper mantle is essential for understanding the dynamics and geochemical evolution of the Earth.

Recent in situ laboratory measurements of electrical conductivity for hydrous olivine containing various amounts of water under high-pressure conditions have been carried out by two groups (polycrystal: Wang et al., 2006; single crystal: Yoshino et al., 2006). However, there is a large discrepancy between them. Wang et al. (2006) measured conductivity of hydrous olivine aggregates at relatively high temperatures (up to 1273 K). Conductivity measurements of hydrated minerals at high temperatures should lead to incorrect measurements because at those high temperatures small polaron (hopping) conduction contributes to the bulk conductivity and also because dehydration is unavoidable due to fast hydrogen diffusion at high temperatures (less than 1000 K). In contrast, Yoshino et al. (2006) measured electrical conductivity at low temperatures (less than 1000K) in which the hydrogen diffusion rate is sufficiently slow, and successfully separated contributions of hopping from proton conduction. However, Yoshino et al. (2006) did not determine the electrical conductivity of hydrous olivine as a function of water content. To directly estimate water content in the upper mantle from electromagnetic observations we determined electrical conductivities of a series of olivine aggregates with various amounts of water at a pressure of 10 GPa in a Kawai type multi-anvil apparatus.

Conductivity measurements were performed on two sets of samples to determine the effect on conductivity of water in olivine: 1) a hydrogen-doped sample and 2) a hydrogen-undoped sample. To minimize water escape from the hydrogen-doped samples, the conductivity measurement was carried out below 1000 K. Three conduction mechanisms were identified from the Arrhenian behavior of the undoped samples, which include a small amount of water. A change in the activation enthalpy indicated that the dominant conduction mechanism changed from proton conduction to small polaron conduction with increasing temperature. At temperatures above 1700 K, the activation enthalpy exceeds 2 eV suggesting that the dominant mechanism of charge transport would be ionic conduction. The conductivity increased with increasing water content. The activation enthalpy for proton conduction tends to decrease slightly with increasing water content. The activation enthalpy determined for each run had similar values (~0.9 eV). Taking the water concentration dependence of activation enthalpy into account for proton conduction, all data was fitted to the electrical conductivity formula  $\sigma = \sigma_0 I \exp[-E_I/kT] + \sigma_0 H \exp[-E_H/kT] + \sigma_0 P C W \exp[-(E_0 - \alpha C W^{1/3})/kT]$ , where  $\sigma_0$  represents a pre-exponential term, CW is the water content in weight percent, E is the activation enthalpy, E0 is the activation enthalpy for proton conduction at very low water concentration, alpha is the geometrical factor, k is the Boltzmann constant, T is absolute temperature and subscripts I, H and P denote ionic, hopping (small polaron) and proton conduction, respectively.

The conductivity jump at the 410 km discontinuity (olivine-wadsleyite transition) is much smaller than that previously predicted. Since the contribution of proton conduction to the bulk electrical conductivity decreases with increasing temperature the high conductivity anomaly at the top of the asthenosphere cannot be explained by olivine hydration.