# Some Issues on Hydrogen in Olivine

Ved Mittal[1], Reynold E. Silber[1], Jennifer Girard[1], Shun-ichiro Karato[1]

[1] Department of Geology and Geophysics, Yale University, New Haven, CT, USA.

It is well known that there is considerable amount of water in the mantle, either through direct sampling of mantle xenoliths and basalts or by indirect measurements inferred from electrical conductivity anomalies in the mantle (Karato 2011). The presence of water in the mantle is said to influence many properties of minerals that ultimately play a role in mantle dynamics. Creep strength, the strength of a material to resist deformation under stress, reduces with increasing water content (Karato and Jung 2003). Similarly strain rate, the rate of deformation of a material, increases with increasing water content (Masuti et al. 2019). The presence of water influences seismic attenuation, the dissipation of strain energy, and is greatly enhanced in water-rich olivine samples when compared to the corresponding dry olivine samples (Aizawa et al. 2008). Therefore, it is well understood that water affects properties of minerals in the mantle, and to better understand mantle dynamics of the Earth's interior, the influence of water should be taken into account.

Water is incorporated into olivine, the dominant mineral in the upper mantle, via hydrogen atoms as point defects in olivine's crystalline structure. Charge neutrality is satisfied when either four hydrogen atoms are substituted into a vacant silicon site or two hydrogen atoms are substituted into a vacant magnesium site. There is still debate as to which of these two proposed dissolution mechanisms is favored and how each mechanism might affect the characteristics of olivine.

In order to conduct an experiment quantifying the effect of water, it is essential to ensure the water content in the samples does not change during the experiment. Hydrogen, due to its small atomic size, can diffuse in and out of the sample very easily, making it difficult to constrain the water content in experimental samples. One method is to constrain hydrogen is by incorporating it with titanium, which locks the hydrogen atom at the vacant site (Tollan et al. 2017). However, the presence of titanium to the bound hydrogen atom might change the effect of water in the sample and therefore it is required to quantify the effect of a titanium-hydrogen dissolution mechanism in olivine.

Here we discuss the possible dissolution mechanisms of water in olivine and the challenges faced in incorporating water in olivine for experimental studies.


1. Aizawa, Y., Barnhoorn, A., Faul, U. H., Fitzgerald, J. D., Jackson, I., Kovacs, I. Seismic properties of Anita Bay dunite: an exploratory study of the influence of water. Journal of Petrology, 49, 841-845 (2008).

2. Karato, S., Jung, H. Effects of pressure on high-temperature dislocation creep in olivine. Philosophical Magazine, 83, 401-414 (2003).

3. Karato, S. Water distribution across the mantle transition zone and its implications for global material circulation. Earth and Planetary Science Letters, 301, 413-423 (2011).

4. Masuti, S., Karato, S., Girard, J., Barbot, S. D. Anisotropic high-temperature creep in hydrous olivine single crystals and its geodynamic implications. Physics of the Earth and Planetary Interiors, 290, 1-9 (2019).

5. Tollan, P. M. E., Smith, R., O'Neill, H. St. C., Hermann, J. The response of the four main substitution mechanisms of H in olivine to $H_2O$ activity at 1050 $^0$C and 3 GPa. Progress in Earth and Planetary Science, 4:14 (2017).