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Investigation of the crystal structure of a low water content hydrous olivine to 29.9 GPa: A high-pressure single-crystal X-ray diffraction study

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Abstract

Olivine is the most abundant mineral in the Earth's upper mantle and subducting slabs. Studying the structural evolution and equation of state of olivine at high-pressure is of fundamental importance in constraining the composition and structure of these regions. Hydrogen can be incorporated into olivine and significantly influence its physical and chemical properties. Previous infrared and Raman spectroscopic studies indicated that local structural changes occur in Mg-rich hydrous olivine (Fo ≥ 95; 4883–9000 ppmw water) at high-pressure. Since water contents of natural olivine are commonly <1000 ppmw, it is inevitable to investigate the effects of such water contents on the equation of state (EoS) and structure of olivine at high-pressure. Here we synthesized a low water content hydrous olivine (Fo_{95}; 1538 ppmw water) at low SiO_2 activity and identified that the incorporated hydrogens are predominantly associated with the Si sites. We performed high-pressure single-crystal X-ray diffraction experiments on this olivine to 29.9 GPa. A third-order Birch-Murnaghan equation of state (BM3 EoS) was fit to the pressure-volume data, yielding the following EoS parameters: V_{T0} = 290.182(1) Å^3, K_{T0} = 130.8(9) GPa, and K'_{T0} = 4.16(8). The K_{T0} is consistent with those of anhydrous Mg-rich olivine, which indicates that such low water content has negligible effects on the bulk modulus of olivine. Furthermore, we carried out the structural refinement of this hydrous olivine as a function of pressure to 29.9 GPa. The results indicate that, similar to the anhydrous olivine, the compression of the M1-O and M2-O bonds are comparable, which are larger than that of the Si-O bonds. The compression of M1-O and M2-O bonds of this hydrous olivine are comparable with those of anhydrous olivine, while the Si-O1 and Si-O2 bonds in the hydrous olivine are more compressible than those in the anhydrous olivine. Therefore, this study suggests that low water content has negligible effects on the EoS of olivine, though the incorporation of water softens the Si-O1 and Si-O2 bond.

Keywords: Hydrous olivine, structural refinement, single-crystal X-ray diffraction, high pressure