Crustal chemistry and compressibility of Fe^{2+}- and oxygen vacancy-rich aluminous bridgmanite: Implications for lower mantle structure and dynamics

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Seismological studies have inferred the presence of small scale (~10 km) dense bodies in the Earth's lower mantle through seismic scattering. A numerical modeling also demonstrated the presence of basaltic crust in the lower mantle and the increase of its amount with increasing depth. These studies suggest that significant amounts of subducted basaltic crusts have been accumulated in the lower mantle, which can affect the physical properties and chemical evolution of the lower mantle and mantle dynamics. In this study, we present crystal chemistry of bridgmanitein mid-ocean ridge basalt (MORB) system up to 52 GPa at 2000 K using our advanced multi-anvil technology. We also synthesized single crystals of bridgmanites with compositions similar to basaltic one at 27 GPa and conducted a compression experiment using a diamond anvil cell.

We found a significant compositional change in bridgmanite with pressure in MORB system. Electron energy-loss spectroscopy shows that basaltic Al-rich bridgmanite has significantly high ferrous iron (75-85%), which is a striking contrast to relatively Al-poor peridotitic bridgmanite (~30%). This result is opposite to previous studies which suggested that the ferric iron content in bridgmanite increases with increasing Al content. The oxygen vacancy component $MgAlO_{2.5}$ is ~10 mol.% below 40 GPa, which is much higher than that in peridotitic bridgmanite (~2-3%). Above 40 GPa, this component disappears whereas the A-site vacancy component of $Fe_{2/3}SiO_3$ appears and the charge-couple Al_2O_3 component increases. The charge-coupled component of $FeAlO_3$ are limited only 2-10.mol% despite the high Fe and Al content and decreases with pressure, implying less importance of this component in basaltic bridgmanite.

Synthesized bridgmanite single crystals have 75% ferrous iron and ~20-30 mol.% of the oxygen vacancy component, whcih is similar to the compositions of basaltic bridgmanite. The single crystal structure analysis shows almost no iron in the octahedral B-site. A compression experiment shows no spin transition in the bridgmanite up to 60 GPa. The synthesized bridgmanite has a pressure derivative of isothermal bulk modulus (K'_{T0}) of 3.1(1), which is relatively low compared with other compositional bridgmanites (~4), indicating that oxygen vacancy-bearing bridgmanite is compressible. The disappearance of the oxygen vacancy component can increase bulk sound velocity and viscosity of basaltic crust, respectively, possibly explaining slab stagnation and plume thinning between 660 km and 1000 km depth. The presence of ferrous iron-rich bridgmanite in the deep lower mantle may also contribute to features of large low-shear-velocity provinces.

Keywords: bridgmanite, basaltic crust, lower mantle, multi-anvil perss