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Elasticity of (Mg,Fe)SiO3 perovskite under high pressure condition

Noriko Takata[1]; Eiji Ohtani[2]; Motohiko Murakami[3]; Takeshi Sakai[4]

[1] Earthscience,Tohoku Univ.; [2] Depart. Earth and Planetary Materials Science, Tohoku Univ; [3] Earth and Planetary Sci., Titech; [4] Inst.Mineral. Petrol.& Econ. Geol., Faculty of Sci.,Tohoku Univ

Recent high resolution seismic studies report lateral velocity variations in Earth's lower mantle that are probably caused by chemical/temperature heterogeneity. In the lower mantle, perovskite is believed to be a dominant phase with minor amount of ferropericlase and calcium silicate perovskite. In order to address this issue, the sound wave velocity measurements of lower mantle minerals are essentially required. The sound velocities of pure $MgSiO_3$ perovskite have been studied by Brillouin scattering spectroscopy up to 100 GPa (Murakami et al., 2007), but the effect of chemical impurities on $MgSiO_3$ perovskite still remains unclear. The sound velocities of aluminum bearing $MgSiO_3$ perovskite have been recently reported and the results suggest that aluminum content of $MgSiO_3$ perovskite is a possible cause for seismic heterogeneity in the lower mantle (Jackson et al., 2004, 2005). However, the sound velocities of iron bearing $MgSiO_3$ perovskite have not been reported experimentally yet due to the experimental difficulties.

Here we report the aggregate shear wave velocities of $(Mg_{0.96},Fe_{0.04})SiO_3$ perovskite up to 48 GPa using Brillouin scattering technique. At ambient pressure measurement, we synthesized $(Mg_{0.96},Fe_{0.04})SiO_3$ perovskite sample at 23 GPa and 1300 degree in a multi anvil press and polished the recovered sample to a platelet with parallel sides and a thickness of about 0.03 mm. At high pressure measurements, we synthesized $(Mg_{0.96}, Fe_{0.04})$ SiO_3 perovskite in a diamond anvil cell from $(Mg_{0.96},Fe_{0.04})SiO_3$ pyroxene powder by CO_2 laser heating above 25 GPa which is thermodynamically stability field of perovskite. We used a symmetric diamond anvil cell with a 0.3 mm culet size and loaded pyroxene powder into a 0.1 mm hole drilled in a rhenium gasket and sandwiched between NaCl as a pressure medium. Pressure was determined by raman shift of diamond T2g mode (Akahama and Kawamura., 2004). In all Brillouin scattering measurements, the scattering angle was a 50 degree and the scattered light was analyzed by a tandem Fabry-Perot interferometer.

The shear wave velocity (Vs_0) and the shear modulus (G_0) of $(Mg_{0.96}, Fe_{0.04})SiO_3$ perovskite at ambient pressure are 6.38(3) km/sec and 170.3(18) GPa, respectively. Those results for both Vs_0 and G_0 are about 2% lower than those of $MgSiO_3$perovskite (Murakami et al., 2007).

We found that the pressure derivative of shear modulus ($(dG/dP)_0 = G_0$') of $(Mg_{0.96},Fe_{0.04})SiO_3$ perovskite is 1.41(1), which is 10 % lower than that of $MgSiO_3$ perovskite (Murakami et al., 2007). On the basis of these results, we calculated that about 3 wt% compositional contrast of iron of $MgSiO_3$ perovskite can account for the 2 % heterogeneity of shear wave velocity observed in the lower mantle at 50 GPa(Houser et al., 2008). These results indicate that the effect of iron content of $MgSiO_3$ perovskite is more sensitive than that of aluminum. Therefore the compositional contrast of iron of $MgSiO_3$ perovskite could be a plausible candidate of the seismic lateral heterogeneity in the lower mantle.