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Elasticity of $MgSiO_3$ glass to pressures of the transition zone

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Geophysical observations suggest the presence of liquid silicates in regions at the top of the transition zone and at the core-mantle boundary. In addition, a mainly silicate magma ocean probably played a crucial role in the evolution of the early Earth. For these reasons understanding the physical behavior of silicates melts at high pressures is important. In situ experimental investigation of the physical properties of silicate melts at high pressures poses substantial technical difficulties, and computer simulations are nowadays the most effective method to explore the elasticity and the density of such material at relevant conditions of the deep Earth. Due to these difficulties, glasses are often used as “frozen” proxies of melts for experimental studies of their physical properties. Here we present the pressure dependence of sound velocity of $MgSiO_3$ glass measured by Brillouin spectroscopy in the diamond-anvil cell across the whole pressure range of the upper mantle and transition zone. We measured both compressional and shear velocity at 36 different pressures both on compression and decompression. Fixing the starting density to 2.742 $\pm$ 0.003 g/cm^3, we determined both bulk modulus K_{S0} and shear modulus G_0, and their pressure derivatives at ambient conditions to be K_{S0} = 76.2 $\pm$ 1.0 GPa, G_0 = 40.11 $\pm$ 0.32 GPa, $(\partial K_S/\partial P)_0$ = 3.04 $\pm$ 0.23, and $(\partial G/\partial P)_0$ = 0.46 $\pm$ 0.06. We observe two discontinuities of the pressure dependence of both compressional and shear velocity at 7 $\pm$ 2 GPa and at 21 $\pm$ 1 GPa. These two discontinuities take place at pressures at which: (a) changes in the pressure dependence of both Si-O-Si bending and Si-O stretching vibrations of the polymerized SiO_4 network were observed in the same glass by laser Raman scattering [1], and (b) new spectral features were observed by X-ray Raman scattering [2].The velocities measured upon decompression are significantly different from those measured during compression. The whole of our velocity measurements in compression and decompression suggest that $MgSiO_3$ glass is subject to a multi-step pressure-induced irreversible densification. We estimate that the overall density increase is of the order of 2 percent after complete decompression. We will discuss issues related to the accuracy of density determination from high-pressure Brillouin scattering measurements of glasses at ambient temperature.

References

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[2] Lee S.K., et al. (2008) Proc. Natl. Acad. Sci. U.S.A., 105(23), 7925-7929.