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Spectroscopic evidence for ultrahigh-pressure polymorphism in SiO2 glass

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The densification mechanisms of glass and molten materials under high-pressure conditions remain poorly understood. Knowledge of the high-pressure structure and pressure-induced coordination changes of SiO2 glass are essential to elucidate the origins of anomalous physical properties of more complex silicate melts, which in turn control the formation and differentiation processes within terrestrial planets over geologic time. However, little is known about the properties of amorphous silicates under extreme high-pressure conditions due to experimental difficulties and lack of suitable in-situ experimental probes. Here, we report in-situ high-pressure Brillouin scattering results for SiO2 glass up to 207 GPa, which reveal the results of pressure-induced bonding changes. Direct in-situ acoustic wave velocity measurements clearly show a continuous transformation from a fourfold- to sixfold-coordinated structure that is complete by 40 GPa, and that the dominantly sixfold-coordinated structure is retained at least to 140 GPa. We found an anomalous increase in velocity above 140 GPa, which is not consistent with the extrapolated velocity trajectory of the sixfold-coordinated structure. This previously unobserved behavior likely corresponds to the onset of structural densification associated with a gradual coordination number change from sixfold to a higher coordination state. Such a pressure-induced continuous coordination change in SiO2 glass suggests the possible presence of ultradense magmas deep within the terrestrial planets.

Keywords: structure of glass/melt, elastic wave velocity measurement, Ultrahigh-pressure experiment, magma ocean