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Yield strength of SiO2 glass under high pressure

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The high-pressure behavior of SiO2 glass has attracted considerable attention because of its importance not only in geophysics but also in condensed-matter physics and materials science. It is considered that the coordination number of SiO2 glass increases from four to six at pressures between 25 GPa and 40-45 GPa [Sato and Funamori, 2008]. The yield strength of SiO2 glass is thought to be affected by its coordination state. Actually, it was reported that the yield strength of SiO2 glass decreases significantly with the increase in coordination number, based on the pressure distribution across the sample chamber in a diamond-anvil cell (DAC) [Meade and Jeanloz, 1988]. However, because the yield strength is difficult to measure under high pressure, their results should be verified by other methods. In this study, we have measured the lower limit of the yield strength of SiO2 glass with a DAC by using a radial x-ray diffraction method.

High-pressure in situ radial x-ray diffraction experiments were carried out at BL-18C of Photon Factory. Pressure was generated by using a DAC having a wide window in the direction perpendicular to the compression axis (i.e., radial direction) [Merkel and Yagi, 2005]. Powdered SiO2 glass was uniaxially compressed by using a cubic boron nitride (c-BN) gasket [Funamori and Sato, 2008] and a beryllium outer gasket, which allow us to increase the sample thickness under high pressure and to obtain diffraction profiles through the gaskets. Pressure was determined by the Raman shift of the diamond anvil [Akahama and Kawamura, 2004]. Based on the lattice strain theory proposed by Singh [1993], the strain under uniaxial compression, {Epsilon}d, is expressed as {Epsilon}d = -[t/(6G)](1-3cos^2{Psi}), where t, G, and {Psi} are the differential stress, shear modulus, and the angle between the compression vector and the scattering vector, respectively.

The differential stress generated in SiO2 glass under uniaxial compression was calculated from the {Psi} dependence of the position of the first sharp diffraction peak (FSDP) and the shear modulus estimated by using the literature data of sound velocity [Zha et al., 1994] and density [Sato and Funamori, 2008]. The lattice strain theory well explains the {Psi} dependence measured in this study. The calculated differential stress in SiO2 glass showed a monotonous increase throughout the pressure range of this study, from 10 GPa to 40 GPa. Meade and Jeanloz [1988] reported that the yield strength of SiO2 glass decreased with pressure above 30 GPa. The differential stress measured in this study is close to the yield strength measured by them up to 30 GPa, but is much larger than it at 40 GPa. Since the maximum differential stress attainable by a sample is equal to its yield strength, the reason of this discrepancy is not clear at present. We are planning to make additional and more detailed measurements up to a higher pressure range to clarify the pressure dependence of the yield strength of SiO2 glass.

References

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