Impact of Temperature and Pressure on the Structure of Borosilicate Glasses

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Abstract

The underlying network structure of glasses controls many important and beneficial properties, including their optical, thermal and mechanical attributes. As glasses continue to be developed for increasingly complex uses, these relationships between structure and properties can be further complicated by the glass thermal and pressure histories. Borosilicates are a particular noteworthy example of glasses with significant commercial success, exploiting their beneficial thermal properties in the case of Pyrex®, to current emphasis on mechanical properties for several technological applications. Borosilicate glasses are also especially suited for structural study using NMR spectroscopy, at both short- and intermediate-range length scales, where the former includes boron coordination number and non-bridging oxygen concentrations, and the latter is often comprised of superstructural units involving borate polyhedra. Here we make use of multi-nuclear NMR to investigate how both temperature and pressure impact these structural elements in borosilicate glasses, leading to substantial changes in properties like density and hardness. In particular, boron coordination and superstructural units like the boroxol ring exhibit substantial sensitivity to changes in fictive temperature and high pressure compaction, and are shown to have a pronounced impact on glass properties.

Keywords: NMR, borosilicate, structure, compression, hardness

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