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STRUCTURE AND PROPERTIES OF GLASSES COMPRESSED AT ELEVATED TEMPERATURES

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There have been numerous studies of glass structure as a function of pressure at room temperature, including recent advances in *in-situ* measurements.^{1,2} In contrast, there are many fewer examples of the effects of simultaneous pressure and temperature treatment on glass structure and even fewer extensions of this knowledge to the rationalization of post-compression glass properties. We have recently leveraged hot isostatic compression of glasses to further our understanding of the pressure and temperature impacts on both network structure and related glass properties.^{3,4} Although our approaches are somewhat modest in both temperature and pressure ($\sim T_g$ and <1 GPa), the ability to compress relatively large glass pieces (cm^2) enables significantly more comprehensive characterization.

Pressure-induced structural changes are manifested by changes in both short- and intermediate-range structure, including changes to the local coordination numbers of network forming cations. Boron-containing glasses are particularly amenable to such effects, leading to a change in the populations of 3- and 4-fold coordinated boron atoms.⁴⁻⁶ In this presentation, we describe studies based on hot isostatic compression of several different borate and borosilicate glasses, where changes in short-range structure following both compression and thermal annealing (relaxation) treatments have been examined using solid-state NMR. Changes in boron coordination, arrangement of these polyhedra into various superstructural groups, as well as the impact of compression and annealing on the local geometry of the network modifying sodium atoms, will be discussed. Such changes in network structure are reflected in the pressure-induced properties of these glasses, such as density, elastic moduli, hardness, crack resistance, and overshoot in heat capacity during glass transition. Implications for this behavior and its glass composition dependence will be described.

[1] T. Edwards *et al.*, "Observation of the transition state for pressure-induced $\text{BO}_3 \rightarrow \text{BO}_4$ conversion in glass," *Science* **345** (2014) 1027.

[2] P.S. Salmon and A. Zeidler, "Networks under pressure: The development of *in situ* high-pressure neutron diffraction for glassy and liquid materials," *J. Phys.: Condens. Matter* **27** (2015) 133201.

[3] M.N. Svenson *et al.*, "Pressure Induced Changes in Interdiffusivity and Compressive Stress in Chemically Strengthened Glass," *ACS Applied Materials & Interfaces* **6** (2014) 10436-10444.

[4] S. Striepe *et al.*, "Elastic and micromechanical properties of isostatically compressed soda-lime-borate glasses," *J. Non-Crystalline Solids* **364** (2013) 44-52.

[5] M.M. Smedskjaer *et al.*, "Irreversibility of Press Induced Boron Speciation Change in Glass," *Scientific Reports* **4** (2014) 3770.

[6] M.N. Svenson *et al.*, "Composition-Structure-Property Relations of Compressed Borosilicate Glasses," *Physical Review Applied* **2** (2014) 024006