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Publication date:
2015

Document Version
Early version, also known as pre-print

Unique Effects of Pressure and Thermal History: Implications for Glass Mechanics and Chemical Strengthening

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The properties of glass are determined not only by temperature, pressure, and composition, but also by their complete thermal and pressure histories. Through both experiments and MD simulations, we reveal that glasses of identical composition produced through thermal annealing and through quenching from elevated pressure can result in samples with identical density and mean interatomic distances, yet different bond angle distributions, medium-range structures, and, thus, macroscopic properties. Specifically we show that changes in micromechanical properties (e.g., hardness) and an ion-exchange induced surface compressive stress are more pronounced when a density increase is obtained through thermal annealing rather than through pressure-quenching, since pressure-quenching has larger effect on medium-range order, while annealing has larger effect on short-range structures. On the other hand, the change in other properties such as alkali diffusivity and bulk modulus upon densification is independent of the type of treatment used to induce the density increase. Our work opens a new avenue towards industrially useful glasses that are identical in terms of composition and density, but with differences in some thermodynamic, mechanical, and rheological properties due to unique structural characteristics.