Improving the damage resistance of oxide glasses from knowledge of their structural response to densification

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Abstract

Increasing the hardness and crack resistance of oxide glasses is critical for the development of damage resistant and mechanically durable glasses for advanced applications. These properties can conventionally be measured using instrumented indentation (such as Vickers) that mimics the real-life damage for certain applications. Early indentation experiments have shown that oxide glasses exhibit pronounced tendency to densify under compressive load, in addition to elastic deformation and shear flow. The deformation mechanism affects the build-up of residual stress, and thus the driving force for cracking. Here, we discuss how knowledge of the deformation mechanism and the accompanying pressure/stress-induced structural transformations in the glassy network can be used to design crack resistant glasses. Our results show that high crack resistance can be associated with the ability of the glasses to self-adapt the connectivity of their network under compressive stress, which facilitates densification and thus aids in dissipation of the energy supplied during impact. We have used this knowledge in the design of highly crack resistant aluminoborate glasses. In addition to lowering the driving force for cracking, the glass' resistance to cracking should also be considered, which is likely related to the bond constraint density. High-temperature densification can be used to increase the latter, but typically results in less densification during indentation and thus an increased driving force for cracking. However, by carefully tailoring the glass structure, we show that it is possible to use high-temperature densification to improve hardness and crack resistance simultaneously by avoiding the pressure-induced decrease in densification contribution to deformation. Finally, we also show that the effect of pre-densification on hardness, crack resistance, and ion exchange strengthening characteristics depends on the utilized densification route (thermal vs. pressure). Overall the results suggest that understanding the structural response of oxide glasses to compression can be helpful for improving their damage resistance.

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