Surface Relaxation of Silica Glass

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Silica glass is a single component glass which is the prototype of numerous other oxide glasses and is popular for use in both electronics and optics. The time-dependent variation of structure and properties through relaxation is one of the unique characteristics of glasses. In general, the structural and stress relaxation kinetics of glasses become faster at higher temperatures and can become observable on a practical time scale when the temperature approaches the glass transition temperature. Relaxation kinetics can be studied by measuring time dependence of any glass properties such as density, refractive index, or the shift of an IR vibrational frequency of a major structural component. In silica, the peak wavenumber in FTIR of a structural band was found to correlate well with the metastable equilibrium temperature called “fictive temperature” which can be tracked with time to determine relaxation kinetics [1].

From the comparison of the IR absorption peak shift of bulk glass and the reflection peak shift of the glass surface, it was found that the structural relaxation rate of the silica glass surface is much faster than that of bulk in the presence of trace amounts of moisture in the atmosphere [2,3]. Surface structural relaxation of silica glass was detected at a temperature as low as 500°C, less than $0.5T_g$. Similarly, the surface stress relaxation kinetics of silica glass were found to be much faster than the bulk stress relaxation kinetics [4]. These phenomena are expected to play an important role in thin films and fibers which have large surface area to volume ratios. In this presentation, various phenomena and processes involving surface relaxation of will be discussed. These applications include strengthening thin glass [5,6] and a new explanation for long-standing mysteries such as the compressive stress degradation in ion-exchanged glass [7], crack arrest by sub-critical stress intensity application [8], and the mechanical fatigue limit of glasses [9]. The possibility that surface stress relaxation may be manifested in fiber birefringence and oxidation kinetics will also be discussed.

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