Mechanical relaxation across 13 decades

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Abstract:

We Structural relaxation spectra of DC704 spanning 13 decades from 10 mHz to 100 GHz with few gaps have been collected over a wide sample temperature range using seven different methods. Piezoelectric shear and bulk modulus gauge (PSG, PBG) and PBG resonance measurements were used in the mHz-kHz range, nanosecond acoustic interferometry and impulsive stimulated scattering in the MHz range, and picosecond ultrasonics with time-domain Brillouin scattering and interferometry measurements in the GHz range. Ultrabroadband dielectric relaxation spectra covering a similar range have been determined (also through the use of multiple measurement methods), but dielectric and mechanical relaxation spectra are not generally identical and the coupling between the two may be complex and temperature-dependent. Most heuristic models and fundamental theories are developed in terms of structural relaxation described by density and/or shear dynamics. Thus the need for ultrabroadband structural relaxation measurements has long been clear. Our results allow comprehensive testing of time-temperature superposition for the alpha structural relaxation spectrum from lightly viscous liquid to glass temperatures. They permit determination of bulk and shear viscosities over a wide frequency range. They allow testing of the shoving model that describes the non-Arrhenius temperature dependence of relaxation dynamics for fragile liquids in terms of the instantaneous shear modulus. The results provide a framework for extensive testing of mode-coupling theoretical predictions of alpha and beta relaxation dynamics. Results covering parts of the full 13-decade spectral range will be presented for other materials as well. Now that it is within current experimental capabilities to span an ultrabroadband frequency range in mechanical relaxation spectra, data from additional systems should be collected to determine their commonalities and differences and how those relate to their positions on the fragility scale.