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From Liquid to Solid: Advanced Characterization of Glass Applying Oscillatory Rheometry

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Abstract : Rotational rheometry is standard practice for the viscosity measurement of molten glass, neglecting the viscoelastic properties of this material, especially at temperatures approaching the glass transition. Oscillatory rheometry serves as a powerful toolbox for glass melt characterization beyond viscosity measurements. Heating and cooling rates and the time-dependent visco-elastic behavior influence the temperature where materials undergo the glass transition. This study presents quantitative thermo-mechanical visco-elasticity measurements on three samples in the Na-K-Al-Si-O system. The measurements were performed with a Furnace Rheometer System combined with an air-bearing DSR 502 measuring head (Anton Paar) and a Pt90Rh10 measuring geometry. Temperature ramps were conducted in rotation and oscillation, and the (complex) viscosity values were compared to calculated viscosity values based on sample composition. Furthermore, temperature ramps with different frequencies were conducted, also revealing the frequency-dependence of the shear loss modulus G'' and the shear storage modulus G'. Here, lower oscillatory frequency results in lower glass transition temperature, as defined by the G'-G'' crossover point. This contribution demonstrates that oscillatory rheometry serves as a powerful toolbox beyond viscosity measurements, as it considers the visco-elasticity of glass melts quantifying viscous and elastic moduli. Further, it offers a strong definition of Tg beyond the 10^12 Pas concept, which cannot be utilized with rotational viscometry data.

Keywords : frequency dependent glass transition, Na-K-Al-Si-O glass melts, oscillatory rheometry, visco-elasticity
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