

Time Matters: Predicting Nonequilibrium Properties of Polymer Films

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Polymers are an important class of materials with tremendous applicability, ranging from ordinary household items and packaging materials to organic solar cells. For most purposes, polymers are processed at rates much higher than the inverse of their equilibration time. As a consequence, polymers often fail to equilibrate within the typical processing timescales, causing the macromolecules to freeze in nonequilibrium molecular conformations. This, in turn, can give rise to structural, dynamical, and mechanical properties that differ strongly from those in thermodynamic equilibrium [1]. Despite the exciting possibility to control properties directly by the chosen processing protocol, a rigorous microscopic understanding of the processing-property relations of polymers is still lacking. In this talk, I will discuss our recent experiments [2-4] on polymer films revealing a dimensionless quantitative parameter, which yielded scaling relations with the amount of preparation-induced residual stresses – a macroscopic manifestation of the nonequilibrium molecular conformations, and the lifetime of nonequilibrium states for polymers of various molecular weights. Interestingly, such relations allowed orders of magnitude control over the viscoelastic properties and crystallization kinetics of polymer films of identical thickness.

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