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Deviations in mechanical properties of ultrathin polymer films via surface wrinkling

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In ultrathin polymer films (h $<$ 100 nm), the measurement of stress relaxation and Young's modulus is a difficult problem due to the delicate nature of such thin films and the lack of appropriate measurement tools for this length scale. Recent work has shown that the Young's modulus of ultrathin glassy polymer films can be measured by a wrinkling-based metrology. Interestingly, the modulus of such thin films was observed to deviate considerably from their bulk counterparts. Building off these observations, we have shown that the rate of structural relaxation and the temperature dependence of the film modulus can also be obtained by following the 'relaxation' of strain-induced wrinkling patterns back to their flat equilibrium state. By measuring the decay or relaxation of surface undulations in compressed thin films, we demonstrate that the structural relaxation of the polymer film is highly thickness-dependent and obeys Arrhenius temperature dependence with an activation energy that decreases progressively with decreasing film thickness. This gives rise to an overall broadening of glass transition and to a relatively weak temperature dependence of structural relaxation.