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The Effects of Thin Films and Confinement on Nanopattering

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There is an extensive body of literature on the effects of thin film confinement on the glass transition and dynamics of polymeric materials. Most of this literature focuses on identifying the fundamental ways in which the properties of a polymer are altered when it is confined in a film whose thickness approaches the natural dimensions of the macromolecule. In this presentation we look at the practical example of nanoimprint lithography (NIL) where the polymer thin film is squeezed into the nanoscale cavity of an imprint mold. We correlate incoherent neutron scattering measurements on thin polystyrene (PS) films with the resistance of the material to flow or create patterns during imprint process. As the PS film thickness drops strongly below 50 nm, the neutron scattering reveals a strong suppression of the mean-square atomic displacements (MSD) on the PS chains. Attempts to NIL pattern PS films of similar thickness at temperatures moderately above the glass transition temperature of the bulk material show a resistance to flow or create patterns that depends on the magnitude MSD suppression. Only when the thin films are heated to a high enough temperature for the dynamics in the MSD to sufficiently recover can patterns be realized. This resistance to flow is also encountered after imprinting, when the patterns are heated to temperatures slightly above their bulk Tg. The decay of the pattern back into underlying residual layer is hindered when residual layer thickness is also below approximately 50 nm. These measurements collectively suggest that viscous flow is hindered in thin polymer films. The possible origins of this response are discussed in detail.