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Nanoimprint Lithography: Process Induced Stresses and Pattern Stability

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Nanoimprint lithography is emerging as an economical technique for fabricating polymeric nanostructures. Features as small as 10 nm in a hard master or mold can be faithfully replicated by imprinting this master into a polymer film. At elevated temperatures and pressures, the molten polymer fills the nanoscale cavities of the mold. When the film is cooled to the vitreous state and the mold removed, freestanding polymeric nanostructures remain. In this presentation we illustrate that the NIL process induces large degrees of residual stress into these structures. Upon heating imprinted nanostructures to just above the glass transition temperature of the polymer, a physical relaxation of the nanostructure shape occurs. The features shrink in height and broaden in width with increased annealing time. However, this decay or slumping of the imprinted pattern is not driven by a simple viscous flow. High molecular mass polymer patterns slump faster than their low molecular mass analogs, contrary to the viscosity changes. Rather, the high viscosity resins generate greater shear stresses along the mold interfaces that lead to extensional flow of the polymer in the fill directions of the patterns. This traps residual stresses in the nanostructures when they are cooled into the glassy state. We quantify this slumping process using X-ray scattering and reflectivity techniques for a range of polymers and pattern sizes and explore potential relations with the glass transition of the polymer within the nanostructure.