Molecular Confinement Accelerates Nanometer-Scale Squeeze Flow of Entangled Polymer Films

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At the nanoscale, processes such as nanoimprint lithography squeeze polymers to form patterns during the manufacture of semiconductor devices, organic electronics and optics. Thin films of polymer are important in adhesives, coatings and lubricants. We used a modified nanoscale indentation technique, which pressed a flat "punch" into very thin films of polystyrene to test the nanometer-scale flow characteristics of these films. The punch was much wider than the thickness of the film, forced the polymer to flow around it. This lateral squeeze flow governs the dynamics of polymer movement during processes such as nanoimprint nanomanufacturing. We found an unexpected increase in the squeeze flow of thin films when the film thickness was smaller than 100 nanometers. In the glassy state, the polymer elastic and yield constants were smaller at the nanometer scale than in the bulk, but were not a function of molecular weight. When heated into the viscous state, films of high molecular weight were softer than films of lower molecular weight. Both of these results run counter to conventional wisdom in polymer physics developed over the last 50 years, and have profound consequences for nanometer-scale manufacturing in polymers.

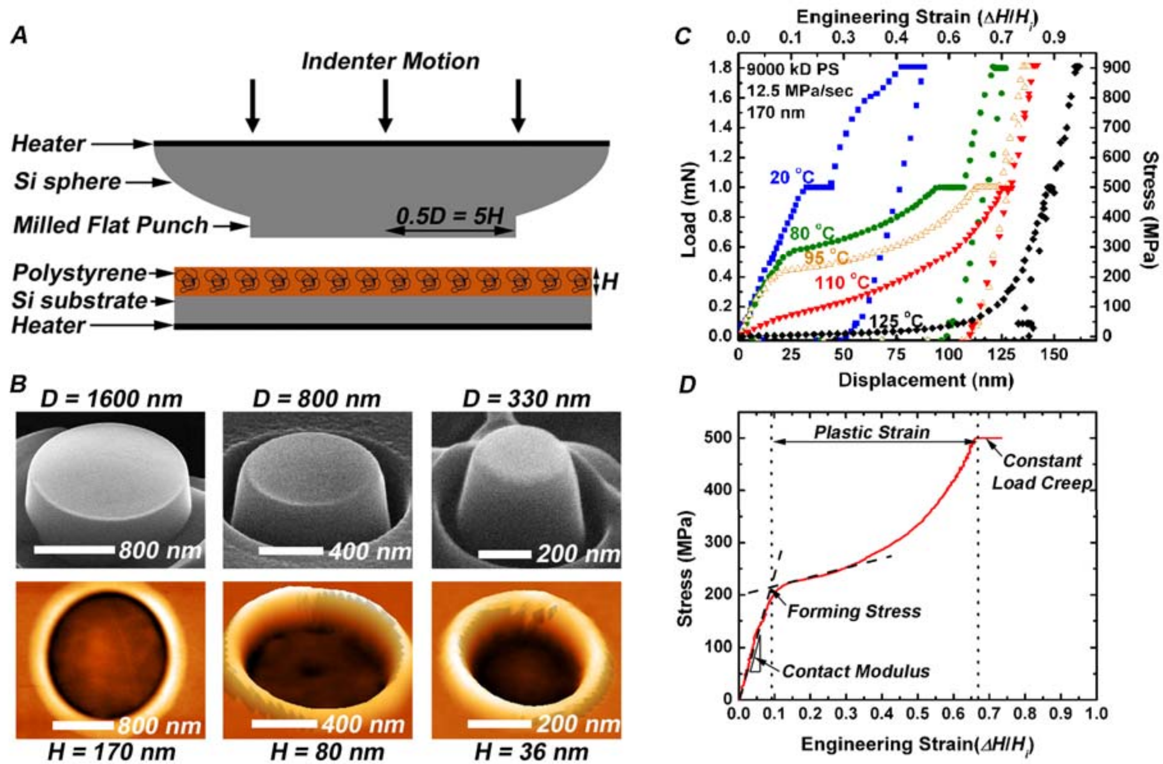

Figure 7.7: Schematic of flat punch indentor and example images of indentor and indented polymer. The stress-stain curves can be generated over a large temperature range, and clearly show elastic and plastic properties of the polymer film.

Rowland, H. D., W. P. King, J. B. Pethica, and G. L. W. Cross, "Molecular Confinement Accelerates Deformation of Entangled Polymers During Squeeze Flow," *Science*, 322, 720-724, October 2008.