Nanometer-Scale Polymer Flow during Nanoimprint Lithography

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In nanoimprint lithography (NIL), a polymer is squeezed between a nanostructured template and substrate. This polymer squeeze flow governs the dynamics of NIL pattern formation. NIL replication fidelity, process time and temperature, and the ability to manufacture densely packed features all critically depend upon this squeeze flow.[1]

We have made stress-strain measurements of nanometer-scale polymer squeeze flow using instrumented nanoindentation.[2,3,4] In these experiments, a flat punch is made parallel with a thin, supported polymer film in a configuration that mimics NIL. The initial polymer film thickness is in the range 30-300 nm, where the punch is large compared to this initial thickness to produce self-consistent measurements over the entire experiment. The polymer is squeezed to a thickness of about 5 nm, and the squeezing force is continuously measured during the process.

Measurements on high molecular weight (MW), entangled polystyrene films showed unexpected results. In the glassy state, the elastic modulus and yield strain decreased with decreasing film thickness, regardless of MW. When heated into the viscous state, high MW films flowed more easily than low molecular weight films. This talk summarized these results and reports their relevance for NIL and other nano-manufacturing schemes.

[1] H. D. Rowland *et al.*, Journal of Micromechanics and Microengineering **15**, 2414 (2005).
[2] G. L. W. Cross *et al.*, Review of Scientific Instruments **79** (2008).
[3] H. D. Rowland *et al.*, Acs Nano **2**, 419 (2008).
[4] H. D. Rowland *et al.*, Science **322**, 720 (2008).

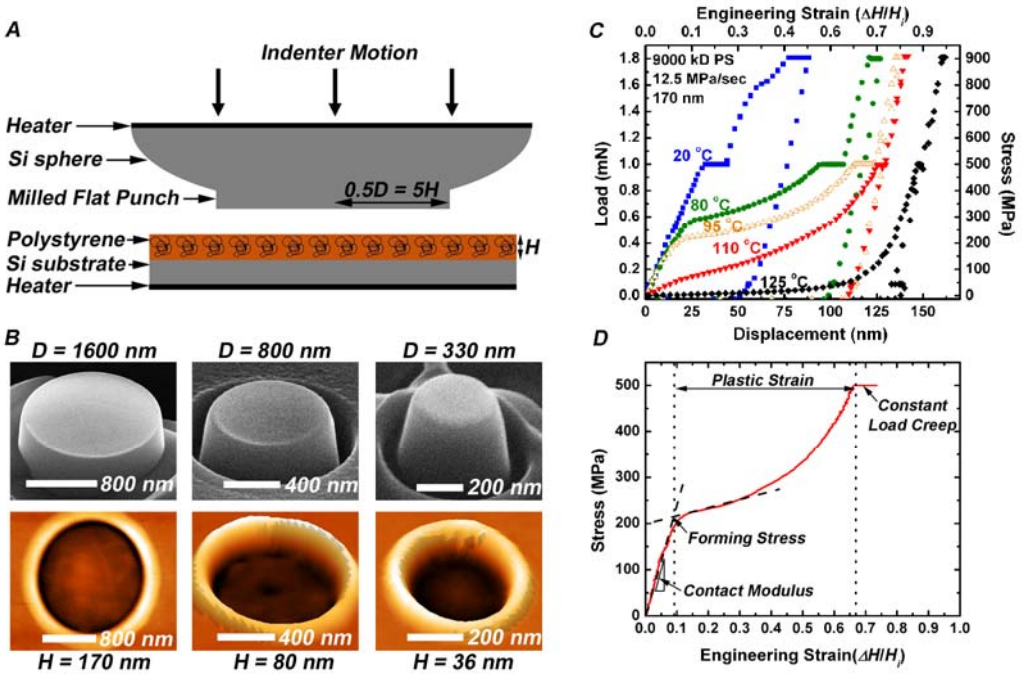

Fig 1: *Nanometer-scale polymer squeezing measures polymer flow properties relevant to NIL.* A) A flat punch is larger than the film thickness, and squeezes the thin film from an initial film thickness of 30-300 nm to a final film thickness about 5 nm. B) Example images of the punch and film. C) Measured stress-strain for a polystyrene film over a range of temperatures, where initial thickness was 170 nm and MW = 9000 kD. D) Example data showing film elastic and plastic response.