Modeling the enhancement of NIL stamp-bending compliance by backside grooves: mitigating the impact of wafer nanotopography on residual layer thickness

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1. Motivation
- Wafer-scale nonuniformity of residual layer thickness (RLT) remains a challenge in thermal nanoimprint lithography (NIL).
- The use of backside grooves etched into a silicon stamp [1] can provide long-range flexibility to conform to stamp nanotopography, while retaining short-range stamp rigidity to limit pattern-dependencies.
- The compliance of such stamps needs to be modeled to enable selection of groove geometries.
- Aim: achieve adequate stamp compliance without making fabrication unnecessarily difficult or consuming a great deal of silicon area with unnecessarily wide flexures.

2. Modeling grooved stamp deflections
Our semi-analytical model for the elastic deflections of a structured stamp captures local indentation, transverse shearing, and bending. The model has been calibrated against finite-element simulations for ranges of initial wafer thicknesses and groove widths and depths.

3. Propagation of parasitic nanotopographies to RLT variation: simulations incorporating a measured wafer topography
- Measurements of the surface roughness of three virgin silicon wafers (above) show that the amplitude of nanotopography is approximately proportional to its wavelength up to scales of 200 nm.
- We simulated a thermal NIL process (right) in which the stamp was assumed to have the topography measured from the SSP wafer.
- Simulations indicate that etched backside grooves in the stamp allow the stamp to conform more easily to the substrate, enabling substantial reductions in both mesa to mesa and within-mesa RLT variation, compared to a grooveless stamp of the same original thickness.
- Meanwhile, the ability of grooves mechanically to 'decouple' adjacent mesas with differing protrusion pattern densities is investigated in our recent work [9].

4. Limiting systematic residual layer thickness variation
A structured stamp with narrow flexures separating thicker feature-carrying mesas gives smaller systematic RLT variation than a uniformly thin stamp.

5. Outlook
- Structured stamps offer short-range stamp rigidity combined with longer-range flexibility.
- Longer-range flexibility enables stamps to conform to random stamp/substrate undulations, improving wafer-scale RLT uniformity.
- Our simulation model allows these benefits to be quantified and stamp geometries selected.

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References