Multi-Phase Flow Model of the Jet-and-Flash Imprint Lithography (J-FIL) Process

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Jet-and-Flash Imprint Lithography (J-FIL) uses low viscosity, UV-curable resist for scalable manufacture of a variety of nano-structures on rigid and flexible materials at standard ambient temperature and pressure. The J-FIL process consists of the controlled dispensing of photo-polymer drops via ink-jet, template filling during imprint, UV-cure (flash), and finally the lift-off of the template from the patterned substrate. Among the underpinning physics of J-FIL, coupled capillary hydrodynamics and structural mechanics are pivotal. We explore several modeling and simulation approaches to address the mechanics of manufacturing-scale processes that involve large aspect ratios and disparate length scales. We investigate levels of computational complexity with the aim of qualifying these approaches based on their efficacy in relating J-FIL parameters (e.g. viscosity, substrate flexibility, process speed) to imprint quality.

At the manufacturing scale, the imprint process involves thousands of micro-scale drops. Our simulations of the merging of drops are based on Reynolds lubrication theory supplemented by interface tracking. As a step towards model verification, we perform a comparison between volume-of-fluid and level-set simulations of a single drop. It is found that tracking drop-merger and template filling at the manufacturing scale is computationally intractable even with the reduction in complexity inherent in lubrication

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theory.

We propose a thin-film two-phase flow model for use in manufacturing-scale simulations of the imprint phase of the J-FIL process. The model is an analog to Darcy flow in partially saturated porous media. This coarse-graining approach eliminates the need for interface tracking. We demonstrate the potential use of this model at the manufacturing-scale by showing preliminary results over imprint areas that include hundreds of drops.