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

Andrew Cochrane †, Kristianto Tjiptowidjojo ‡, Akhilesh Jain *, Roger T. Bonnecaze *, P. Randall Schunk ‡§

† Nanoscience and Microsystems Program
1 University of New Mexico
Albuquerque, NM 87131

‡ Department of Chemical and Biological Engineering
1 University of New Mexico
Albuquerque, NM 87131

*University of Texas at Austin
McKetta Department of Chemical Engineering
200 E. Dean Keeton St.
Austin, TX 78712

§ Sandia National Laboratories
Albuquerque, NM 87185

To be presented at the 17th International Coating Science and Technology Symposium, September 7-10, 2014, San Diego, CA

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

1 Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy’s National Nuclear Security Administration under Contract DE-AC04-94AL85000
2 Unpublished. IS CST shall not be responsible for statements or opinions contained in papers or printed in its publications.
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.