Two-Phase Flow and Structural Deformation Models for Nanoimprint Lithography

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Jet-and-Flash Imprint Lithography (J-FIL) is an attractive method for high-throughput manufacturing of nano-patterned materials and devices. J-FIL deposits high densities of drops of low viscosity UV-curable resist for scalable manufacture of various nano-structures on rigid and flexible materials at standard atmospheric temperature and pressure. Economically viable patterning requires complete drop merger, pattern filling, uniform residual layer thickness (RLT) across the substrate and short processing times. Process optimization is enabled by manufacturing scale models that resolve physics across disparate length scales of the patterns (~50 nm), the drops (~10 μm), and the substrate (~10 cm). We develop a two-phase flow model for fluids in the template-substrate gap using a variety of model-order-reduction techniques. A key aspect of the model is that compressibility and dissolution of trapped gas are captured in manufacturing-scale simulations. Using this capability, we predict processing rate sensitivities to gas dissolution and viscous resistance. We further develop the manufacturing simulations by also coupling two-phase flow with structural mechanics for modeling a flexible tensioned web. Coupled models are used to explore relationships between processing parameters in the stamping and rolling imprint modes, these parameters include tension, RLT uniformity, web speed, cure window and minimum thickness.

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