Optimizing Filling of Anisotropic Templates in UV Nanoimprint Lithography

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Abstract:

A key to the successful deployment of UV nanoimprint lithography (UV-NIL) to integrated circuit (IC) manufacturing will need to break the bottleneck of UVNIL. There are several experimental observations and analysis which indicates template fluid filling, the bottleneck, is strongly related to the structure of a template and the configuration of droplet placement. Therefore, through the insights gained from a comprehensive model which captures major physics involved with fluid flow, rational design of a template or a droplet pattern could be employed in the future to achieve a low defectivity and high throughput UVNIL process. Thus, our research problem is finding an optimal UVNIL process setting which run at the shortest fluid filling time that leads to an acceptable defect density.

From experimental observations, it is found that the optimized droplet placement can significantly reduce defect density while not compromising the throughput of UVNIL. The challenge is to optimally place the droplets on the substrate under the template. This is particularly challenging for anisotropic templates, such as lines and spaces, where the filling process is highly directional. Currently, these optimized droplet placement is found by trial and error which is expensive and laborious. Our ultimate research goal is development of computer simulations which is a faster and inexpensive means to find optimizing droplet placements.

Simulation of UVNIL using a template with line and space patterns with nine droplets dispensed in a square arrangement is shown in Fig. 1. It was founded that the droplets are stretched when UVNIL is carried out with templates having line and space patterns. The non-circular shape is a result of the difference in flow permeability in x and y directions[1]. The higher permeability in y-direction compare to x-direction leads to the droplet spreading faster in the y-direction compared to the x-direction and forming straight channels (Fig. 1). However, the simulation result shown in Fig. 1 is not completely satisfactory because straight channels of unfilled regions was not observed in simulation. We believe the discrepancy exists between the experimental result and simulation can be mitigated by considering more accurate capillary pressure boundary condition.

Here we present a theory and simulation for fluid filling for anisotropic templates. The theory includes an anisotropic permeability to account for the variation in flow resistance parallel to the template. It also includes a varying capillary pressure (Fig. 2) that depends on the position of the gas-liquid interface relative to the orientation of the template. This theory is integrated into a simulation of template filling and droplet motion and merging for up to 1000 droplets to optimize droplet positions under different anisotropic templates.

Reference:

[1] Jain, A.; Spann, A.; Cochrane, A.; Schunk, P. R.; Bonnecaze, R. T., Fluid flow in UV nanoimprint lithography with patterned templates. Microelectronic Engineering 2017, 173, 62-70.

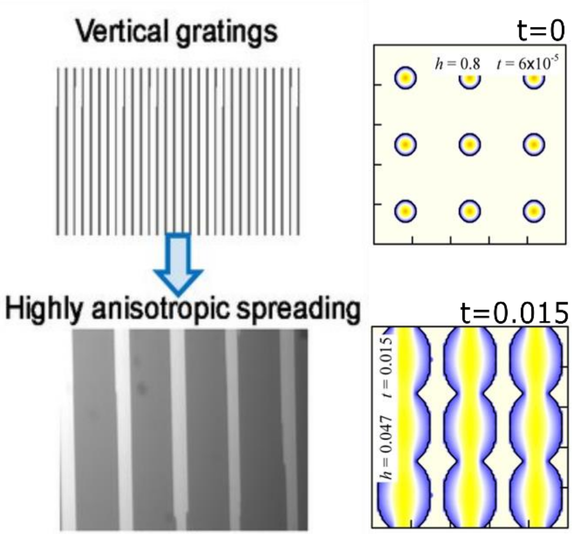

Figure 1. Fluid spreading with a patterned template with vertical grating. In experiment, straight channels of fluid and unfilled cavity formed (left figure). Simulation result also shows an anisotropic flow (right figure), qualitatively similar to the experimental result[1]

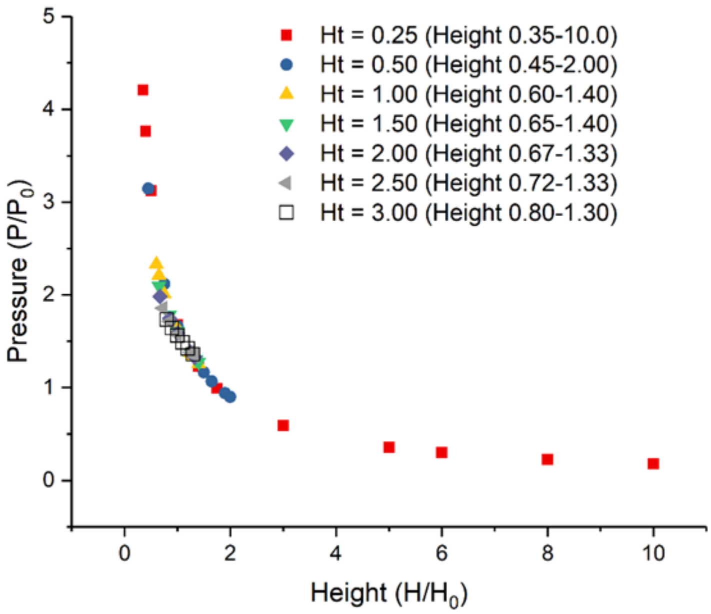

Figure 2. Capillary pressure calculated under various configuration created by vertical grating template. The comment next to legend present the range of height where stable interface existed in Surface Evolver simulation.