Polymer filling behaviors with imprinting velocity in NIL

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Nanoimprint lithography (NIL) is next generation technology with wide application area, and interests have been growing with the development of nano-scale manufacturing industry. Although many researchers[1-4] have studied several issues in NIL, various defect problems such as deformations and insufficient filling still remain. In thermal NIL, since polymer viscosity varies with temperature and processing conditions are quite severe due to high pressure, it is necessary to analyze the filling characteristics of the polymer. In this study, numerical simulations are carried out to investigate the polymer filling behaviors according to imprint velocities. As imprint velocity affects polymer shape, various imprint velocities are compared to determine the filling behaviors at a stamp geometry at which filling behaviors are varied. In this study dimensionless stamp geometry of 0.26 with 300nm-thick is considered, and Polymethyl methacrylate (PMMA) is used as a polymer with incompressible non-newtonian model as in a Cross-WLF model[5].

Figure 1 shows the comparison of polymer shape from this simulation with the previous study[4], and it can be seen that these shapes have quite similar filling behaviors. Variation of peak position from the wall with moving distance is plotted in Fig. 2. As moving distance increases, the peak position is shifted from the side wall to the center of the cavity. Then a single peak is formed by dominant viscous flow. However, at the beginning of NIL, horizontal or concave shapes are appeared due to the capillary flow effect. Figure 3 shows the variation of h_d, defined as the difference between the maximum polymer height (h_p) and the polymer height at side wall (h_s), with the imprint velocity in the polymer flow fields. h_d value increases with the imprint velocity with developing the squeezing flow. From the highest peak (h_f = 290 nm) at viscous flow regime (above 10 nm/s), it gradually decreases due to shifted peak position abovementioned at Fig. 2. It can also be seen that near the imprint velocity of 10 nm/s, polymer flow type changes from capillary to viscous flow. When the imprint velocity is less than 10 nm/s, capillary flow is dominant, and horizontal or concave polymer shapes are shown. It indicates that polymer flow regimes could be divided by specific velocity at which filling behaviors are changed from

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capillary to viscous flow. In conclusion, as the imprint velocity increases, viscous flow could be occurred with shapes of single or double peak. For low imprint velocity condition, concave or horizontal shape could be appeared by dominant capillary flow. And high imprint velocity involves air trapping close to the edge of the stamp despite of fast filling. Finally, it is expected that the results of this study can be applied to optimize the operating conditions of NIL with the analysis of the polymer flow field characteristics.

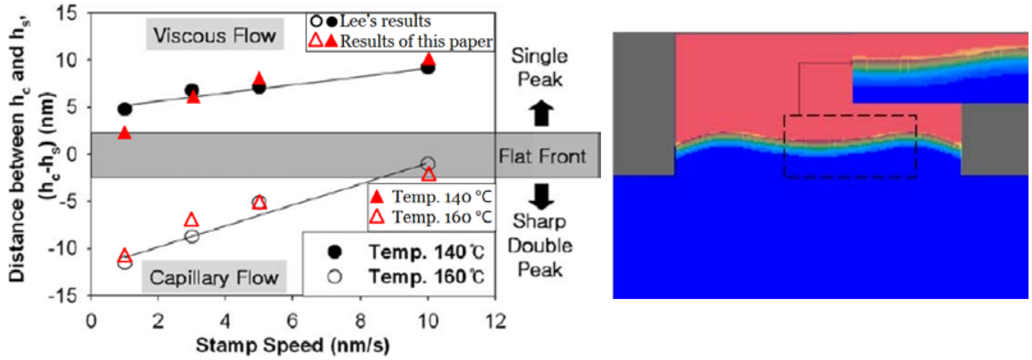

Figure 1. Comparison of polymer filling behaviors from this simulation with previous study[4].

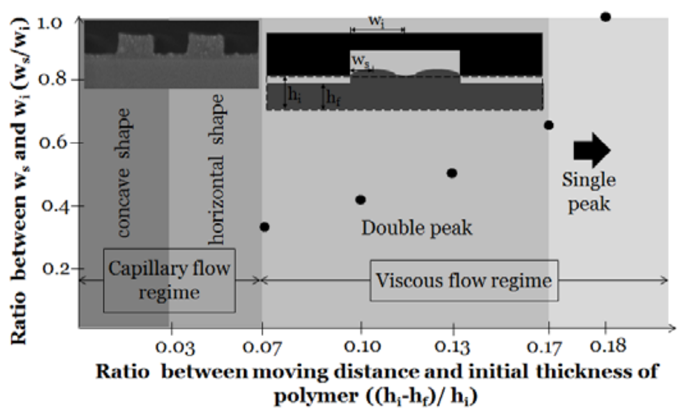

Figure 2. Variation of peak width with polymer moving distance. Where, w_i, w_s, h_f, and h_i are width of stamp, peak position from side wall, final thickness and initial thickness of the polymer, respectively.

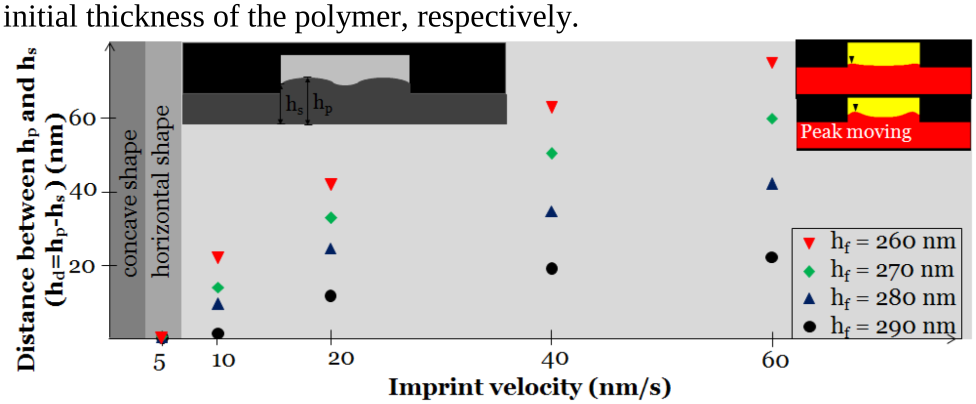

Figure 3. Variation of the peak height (h_d) with imprint velocity for several final thickness of polymer (h_f). Where, h_p and h_s are the maximum polymer height and the polymer height at side wall, respectively.