Filling Characteristics of Imprint Process for Concave Pattern Molds

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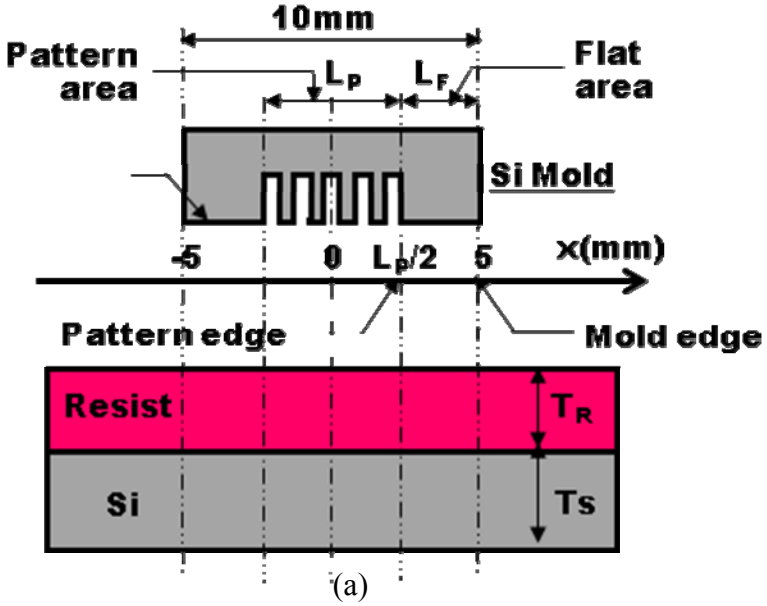
Thermal nanoimprint lithography (T-NIL) is very attractive technique because nano-patterns can be fabricated for various resins. However, pattern defects due to resist filling problem are sometimes observed under the same imprint conditions. Since the defects are frequently generated for concave mold, which has cavity patterns in a large substrate surface, its defect formation mechanism is explored in this report.

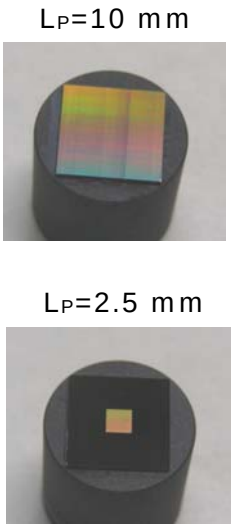
Schematic view of the mold and substrate system is shown in Fig.1(a). 2 μm half-pitch trench patterns are fabricated in (110) Si substrate of 10x10 mm square by the KOH anisotropic etching. The etching depth is about 2.5 μm. Examples of the fabricated molds are shown in Fig.1(b). Note that the resist is pressed by the large flat area, when L_P is small. Polymethylmethacrylate (PMMA) or Polystyrene (PS) is used as the resist. The press conditions are 170ºC, 10 MPa for 15 min. Both the Si substrate and resist thicknesses, T_S and T_R, are changed in our experiments.

The imprint results are shown in Figs. 2 – 5 for the L_P=2.5mm mold, which has large flat area. Figures 2 and 3 show the imprint results for the thick PMMA films. Figure 2 shows the imprint results for T_S= 675 μm. A slight filling defect is observed at the center. Figure 3 show those for T_S= 200 μm. No filling defect is observed in the whole pattern area. The filling characteristic is improved when the substrate thickness is decreased. Figure 4 shows the imprint results for the thin PMMA film. Clear filling defects are observed at both the center and the pattern edge. The filling characteristic is degraded when the resist thickness is decreased. Figure 5 shows the imprint results for the thin PS film. In contrast to PMMA film, no filling defect is observed. When the L_P=10 mm mold is used, good resist patterns are always obtained under all experimental conditions. Pattern defects are generated when the used mold has a flat area. The resist film is first touched to the mold flat area when the mold approaches to the substrate. The resist film is compressed and the mold stops when the force by the compression is equal to the press force. If the distance to the stopping position is less than the mold depth, the filling defects are produced. When the flat area increases and/or the resist thickness decreases, the stopping distance decreases, and the filling defect increases. The rheology characteristics of the used PMMA and PS resins are measured. The storage moduluses of used PMMA and PS are 1 MPa and 0.1 MPa, respectively. Since the PS film is soft, the mold easily puts into the film and the filling defects are small. When the thin substrate is used, the substrate is easily deformed. It is confirmed by the FEM simulation that the substrate is bended to the mold surface.[1] The resist surface becomes closer to the cavity bottom and the resist filling is improved. Note that the resist filling is assisted by the substrate bending.

[1] Y. Watanabe, et al., Abstract of 2011 MNC (Kyoto, Japan, October 2011) 26P-7-107.



(a)



(b)

Fig. 1 Mold and substrate system. (a) Schematic view of the system, (b) examples of used molds

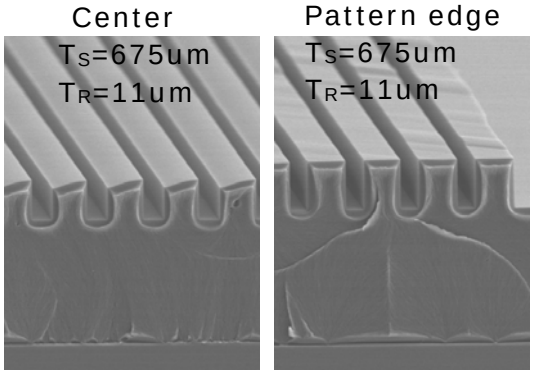


Fig. 2 Imprint result for thick PMMA film at both mold center and pattern edge, when T_S=675μm.

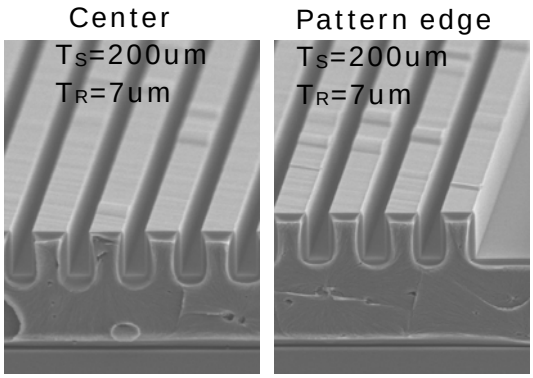


Fig. 3 Imprint result for thick PMMA film at both mold center and pattern edge, when T_S=200μm.

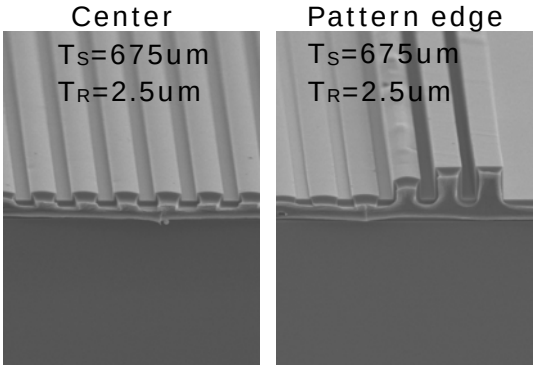


Fig. 4 Imprint result for thin PMMA film at both mold center and pattern edge, when T_S=675μm.

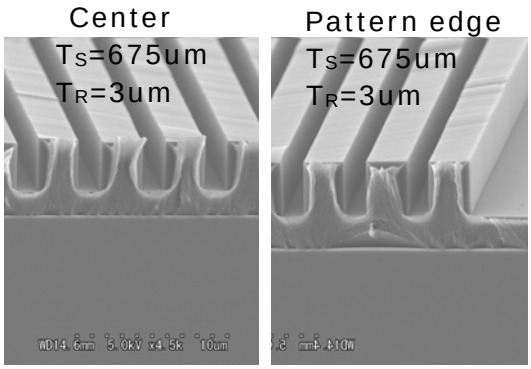


Fig. 5 Imprint result for thin PS film at both mold center and pattern edge, when T_S=675μm.