Injection compression molding of replica molds for nanoimprint lithography

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Nanoimprint lithography (NIL) is expected to be a candidate process as a low cost lithography method for patterned media or very large-scale integration. However, there are some bottlenecks for its practical realization. One of the most critical bottlenecks is the limitation of the durability of the mold. Once a foreign particle gets stuck between the mold and the resist on the substrate, the mold suffers fatal damage. A solution of this problem is using replica molds, i.e., disposable molds.[1] In this paper, we fabricate the replica molds using injection compression molding,[2] which is a conventional technique for molding optical disks such as CDs, DVDs and Blu-ray disks(BDs) and low-cost and high-throughput process.

We used cycloolefin polymer (COP) and polycarbonate (PC). COP has good transmittance of ultraviolet (UV) and suitable for UV-NIL and polycarbonate (PC) has high glass transition temperature (T_g) and suitable for thermal NIL. Ni electroplated stamper (provided by Fujifilm Corp.) has line-and-space pattern with a land width of 30 nm, a height of 60 nm and pitches of 90, 120, 150, 200, 320 nm.[3] The thicknesses of replica mold (Figure1) were 0.6 mm (when mold for DVDs is used) and 1.2 mm (when mold for BDs is used).

Figure2(a) shows the replication results using PC (T_g*:* 145 ˚C) and molds for BDs. The replicated height was plotted as a function of pattern pitch. When the mold temperature became higher (90 → 120 ˚C), the replication degree was better. However, the 90-nm-pitch pattern was not completely replicated with the mold temperature of 120 ˚C. Even though the compression pressure was increased (350 → 390 kN), the replication degree was not improved. Finally, when the polymer temperature was higher (350 → 360 ˚C), the replication of 90-nm-pitch pattern was improved. The effect of the polymer temperature is higher than that of the compression pressure for better replication.

Figure2(b) shows replication results using COP (T_g*:* 100 ˚C) and molds for DVDs. We varied the mold temperature 80-110 ˚C. When the mold temperature was 110 ˚C, the replica mold was demolded after cooled to 80 ˚C. The replication was good in any conditions. The flow property of COP was better than that of PC.

[1] D. Pisignano, S. D'Amone, G. Gigli, R. Cingolani, J. Vac.Sci. Technol. B 22 (2004) 1759.
[2] K. Nagato, T. Hamaguchi, M. Nakao, J. Vac. Sci. Technol. B 29 (2011) 06FG10.
[3] K. Ichikawa, T. Usa, K. Nishimaki, K. Usuki, IEEE Trans. Magn. 44 (2008) 3450.

Figure 1: Optical photo of injection-compression-molded replica mold

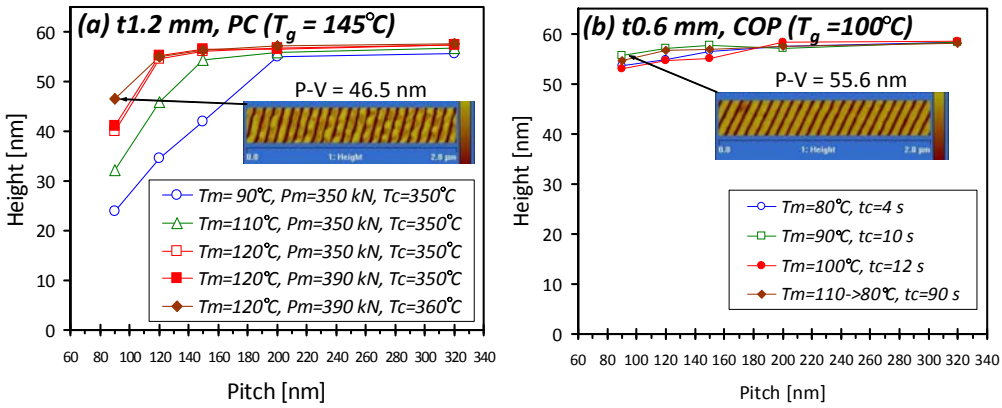

Figure 2: Peak to valley of the nanostructure of replica molds which are replicated by injection compression molding: T_m, P_m, T_c and *tc* mean mold temperature, compression pressure, cylinder temperature, and cycle time respectively. The Ni stamper has line and space pattern with a height of 60 nm, a land width of 30 nm, and pitches of 90, 120, 140, 200, 320 nm. Thickness and polymer of replica mold were (a) 1.2 mm and PC, and (b) 0.6 mm and COP.