Computational Study on 3-D Mold Profile Correction for Resist Shrinkage in Nanoimprint

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Introduction

Precise microstructures such as micro optical elements need flat surface or precise curved structure. As the distortion of the device shape affects optical characteristics, fine and precise processing is demanded. Nanoimprinting as a micro-molding technology is one of the promising process for realizing fine and precise replication of micro structure in cost effectively. However, due to shrinkage of cured resist, the resist profile after curing is distorted and there is a concern about the influence on the device performance [1].

In this paper, we propose a simple and versatile model to predict resist profile by shrinkage for typical structures. Based on the profile estimation, correction of the mold profile is proposed and the distortions for various 3D structures are evaluated by computational works.

Estimation of shrunk pattern profiles and mold correction for 3D

Figure 1 shows schematics of the shrinkage and correction models. Figure 1 a) shows the cross section of the resist pattern. To simplify the estimation of shrinkage process, the resist shrinkage is divided into lateral and vertical directions. For lateral shrinkage, the shrinkage ratio is gradually increases from the substrate, where the resist is fixed on the substrate. On the other hand, the resist is isotopically shrunk in vertical direction. So, a point on the side wall (x,y) is transferred to (x',y') as follows:

$$x' = \frac{1}{2A}(1-y)(1-\alpha_0(1-e^{-\frac{y}{\tau_t(\mathrm{A})}})) \quad , \quad y' = k_s(1-\alpha_0)y \qquad (1),$$

where A is the aspect ratio of the cross section of the structure, α_0 is linear shrinkage rate of the resist, τ_s is the relaxation coefficient and k_s is the correction parameter for volume shrinkage, where the total volume after shrinkage is kept to be $(1-\alpha_0)^3$. Based on the profile prediction after resist shrinkage, the mold profile is automatically corrected to compensate the shrinkage. The side wall profile is expanded to compensate the shrinkage as illustrated in Fig.1 b). For edge of the 3-D structures, the side walls are simply extended and rounded.

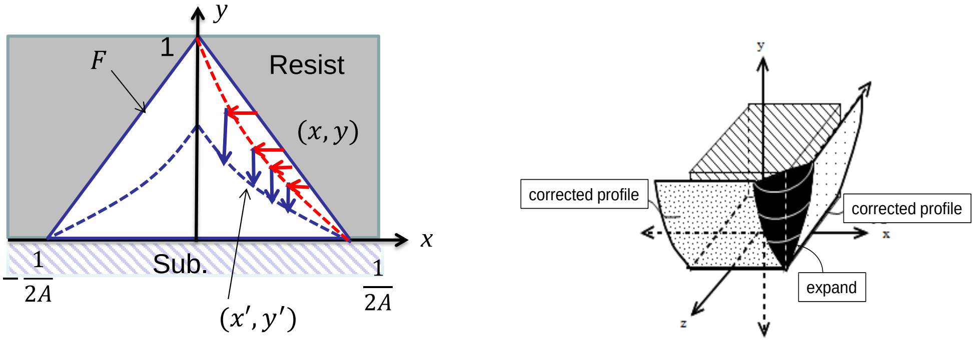
Results and Discussions

The effects of the mold correction are evaluated by computational works, where the resist is isotopically shrunk. Figure 2 shows the mold and resist profiles for pyramidal structures. The left side shows mold structure and right side shows resist profiles after shrinkage. Without shrinkage correction, the mean square error σ is 10% under 10% linear shrinkage (Fig.2 a)). However, the error σ is compensated less than 0.03% (Fig.2 b)). In the same way, spherical structure such as spherical lens structure is the estimated in Fig.3. With correction, the distortion error is compensated down to 1.4%.

As demonstrated, the resist shrinkage could be compensated using simple but universally applicable procedures for mold profile corrections. We believe the method is practical for fabrication of micro optical elements using nanoimprint.

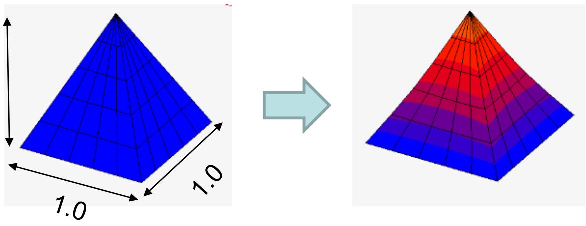
Reference

[1] A. Horiba, et al., *Jpn. J. Appl. Phys.* **51** (2012) 06FJ06.

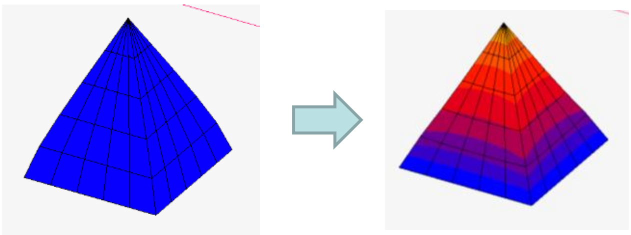


a) Shrinkage model for side wall b) Mold correction at edge

Fig.1. Schematics of the shrinkage and correction models

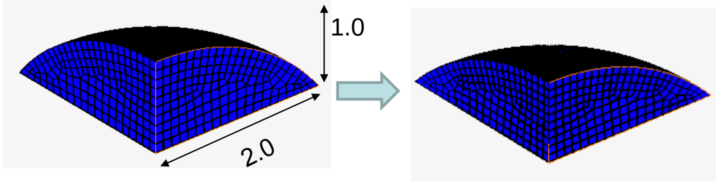


a) Without mold correction (σ=0.10)

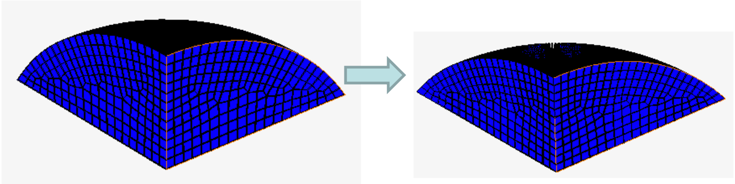


b) With mold correction (σ=0.0029)

Fig.2. Mold profile correction for pyramid structures (Liner shrinkage :10%)



a) Without mold correction (Error in RMS=0.10)



b) With mold correction (Error in RMS=0.014)

Fig.3. Mold profile correction for (Liner shrinkage :10%)