Time Dependent Analysis of the Resist Deformation in Thermal Nanoimprint

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1. Introduction

Nanoimprint lithography (NIL) is promising for low cost and large field micro-nano fabrication. In the thermal NIL process, a high speed imprinting technique was reported, however its details have not been discussed theoretically and experimentally. We have developed a software for the numerical simulation of the time dependent resist deformation and thermal cooling process in thermal NIL processes. In this paper, we investigate the time evolution of the resist profiles.

2. Simulation and Experiment

For the NIL, there have been reported several numerical analysis based on the rubber elastic model [1] or the viscous liquid model [2] but not a viscoelastic model. We developed a simulator based on the viscoelastic model for thermal NIL processes. Fig.1-a shows the schematic diagram of the simulation. The polymer is assumed to be a viscoelastic body based on the standard solid model (Fig.1-b) as follows:

$$[T] = P[I] + [S] = KE_{\mathrm{vol}}[I] + 2G_0\left([E'] - \frac{G_1}{G_0}[E'_v]\right) \quad (1),$$

where [T] is stress tensor, E_{vol} is volumetric strain, [E’] is deviatoric total strain tensor, [Ev’] is deviatoric viscous strain tensor, K is bulk modulus, and G_0 is instantaneous shear modulus.

To obtain the time evolution of the quenched resist profile experimentally, we chose low temperature process condition to have a long deformation time and the sample is quenched after pressing by Aluminum cooling plate to freeze the resist profile (Fig.2).

3. Result and Discussion

Fig.3 shows the simulation and experimental results for 500 nm and 250 nm lines. The simulation and the experiment relatively agree with each other. The narrow pattern takes longer time to be deformed. Fig.4 shows the simulation results of the resist filling rate in variation with the pattern width. The resist deforms logarithmically as time proceeds.

We will further investigate the relation between the viscosity of the resist and filling time for various pattern configurations.

Acknowledgment

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References

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[2] H. Rowland, et al., J. Vac. Sci. Technol. B 23, 2958 (2005).

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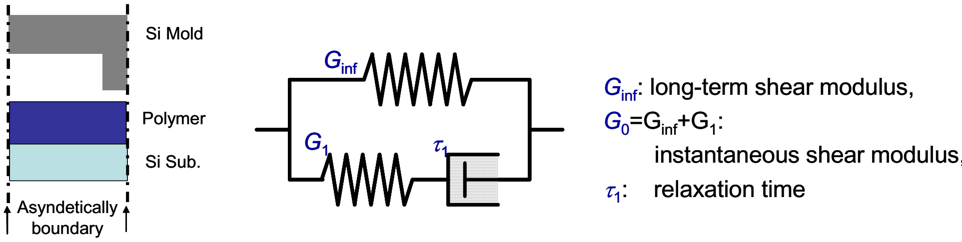
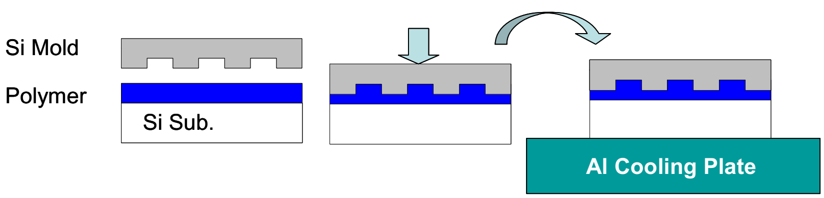


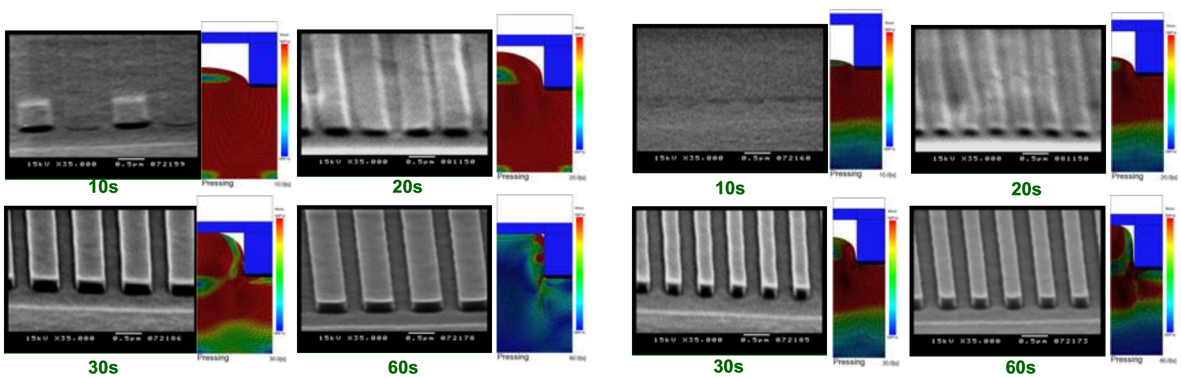
a) Analysis system b) Mechanical model

Figure 1. Schematic diagram of the time dependent resist profile simulation



a) Heating (T>Tg) b) Press c) Quenching (4 °*C*)

Figure 2. Schematic diagram of the experiment for quick cooling process



a) Line width: 500 nm b) Line width: 250 nm

Figure 3. Simulation and experimental results of the resist time evolution profiles (PMMA, M_w=120k, T=140 °*C* , P=5 MPa, Quenched at 4 °*C*)

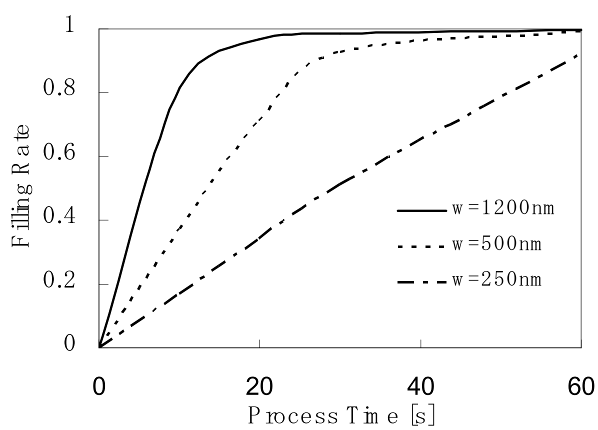


Figure 4. Simulation results of the resist filling rate in variation with the pattern width

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