Simulation Study on Template Releasing Process in Nanoimprint Lithography

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Introduction

Template releasing is key process to approach defect free process in nanoimprint lithography. In the template releasing process, stretching and/or shear stress induce resist fracture or damages. Those defects are significant problem in nanoimprint lithography. Understanding the template releasing mechanism is indispensable for defect elimination. Simulation study is powerful way to understand the process kinetics[1)]. In this report, numerical simulation study on template releasing process has been performed to investigate stress distribution in various releasing conditions and methods.

Simulation model

Numerical simulation is done using conventional finite element method (EFM) under conditions that the resist is viscoelastic body and the template is rigid body. The boundary condition between template and resist is expressed by the following equation where σ_n and σ_s are normal and shear stresses on the boundary.

$$(\sigma_n / P_n)^2 + (\sigma_s / P_s)^2 > 1 \quad \text{1)}$$

, where P_n and P_s are critical normal stress and shear stress to template. As template releasing modes, lift off, peeling and roll to roll releasing are examined as illustrated in Fig.1. In the lift off mode (Fig.1 a)), template is almost vertically removed including slight inclined angle θ to normal direction due to mechanical accuracy (Fig.1 b)). In the peeling mode, the template rotates by point symmetry in radius of curvature L. In the roll to roll mode, the template rotates and feeds substrate (Fig.1 c)).

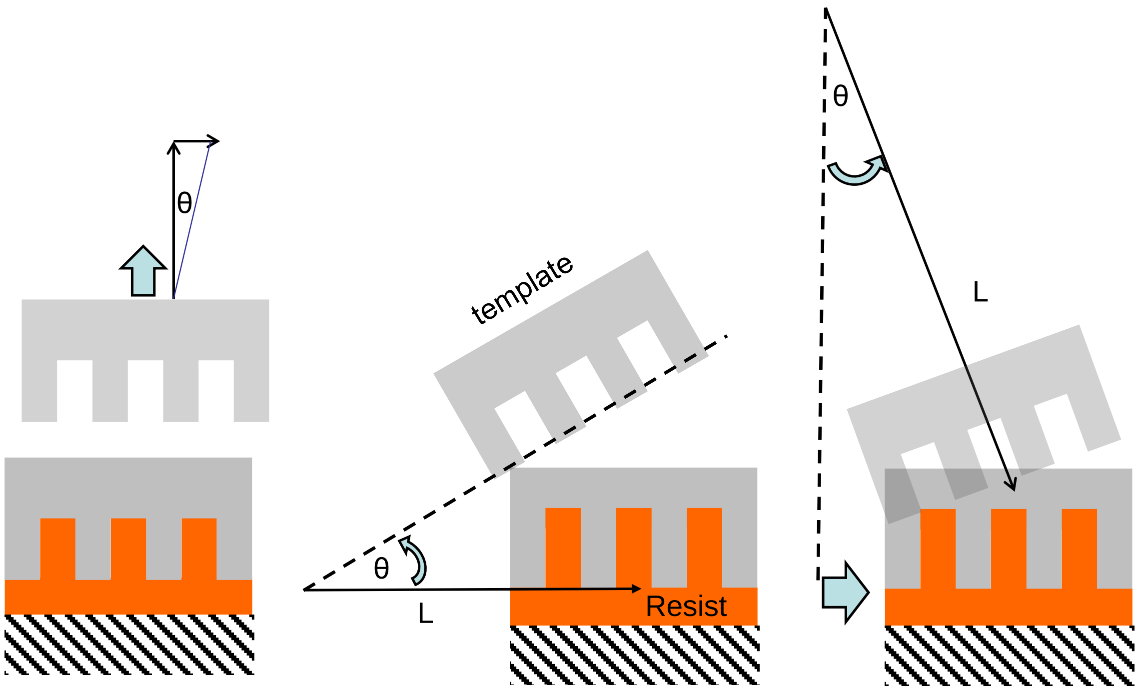
Results and discussions

In this study, a 50nm line & space pattern is examined with 150 nm in height. The resist is PMMA and P_n and P_s are 0.12 MPa and 1.0 MPa, which are estimated from experimental result. Figure 2 demonstrates stretching stress σ_{yy} just before the resist is detached from the template. In those cases, maximum stretching stresses are induced just before the template is detached from resist, because all area along template and resist boundary is gulled. After detached, the stress are relaxed during templates are moving up. Figure 3 demonstrates stress distributions before templates are released from resists. The stress decreases because the shear stresses are decreased as decrement of boundary areas. In this case, peeling mode is the most risky method even if the aspect ratio of pattern is low.

Dependency of stress distributions on the critical stresses P_n and P_s, and geometrical configurations such as rotation angle θ and radius of curvature L will be discussed for stress elimination in template releasing processes.

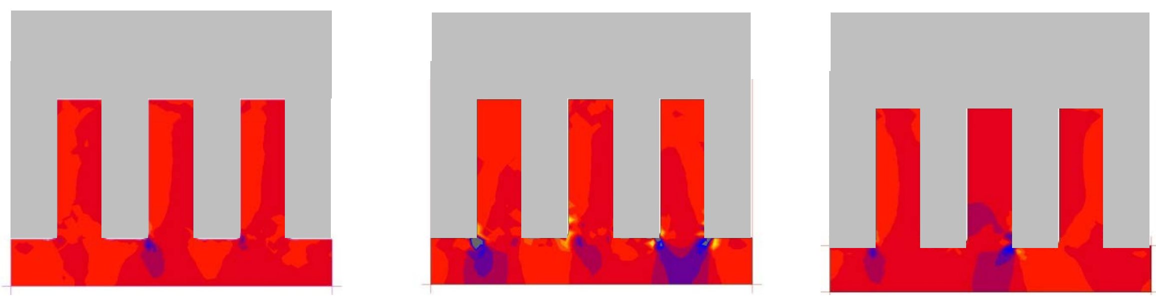
Reference

1) Y. Hirai, et al., J. Vac. Sci. Technol. B 21(2003) 2765.



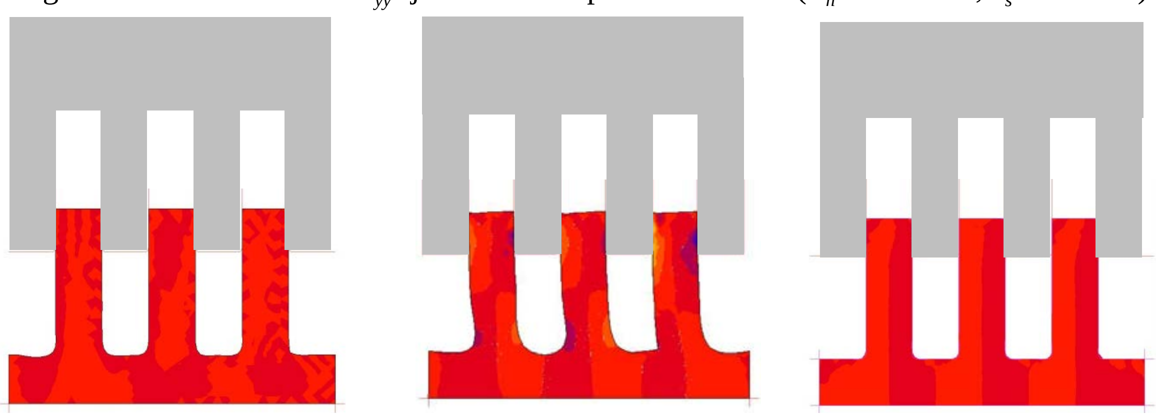
a)Lift off mode b) Peeling mode c) Roll to roll mode

Fig.1. Schematics of template releasing modes



a) Lift off (tan(θ)=1.67e-4) b) Peeling (L=5mm, tan(θ)=3e-5) c) Roll to Roll (L=50mm, tan(θ)=3e-6)

Fig.2. Stress distribution σ_{yy} just before template is detached. (P_n =0.12 MPa, P_s =1.0 MPa)



a) Lift off b) Peeling c) Roll to Roll

Fig.3. Stress distribution σ_{yy} before template is released.