Impact of template stiffness during peeling release in nanoimprint lithography

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Introduction

The template releasing process is an important step in nanoimprint lithography. Due to adhesion between the template and the resist, the imprinted resist is stretched in releasing process. Also, due to bending of template and/or substrate, the resist suffers external bending force. As a result, stress is induced in the resist and fatal defects may appear. Various approaches, either mechanical or chemical, have been proposed in order to reduce the defect formation. One of the popular approaches is peeling release using flexible template, however the mechanical characterizing still lacks and optimization of the method has not been discussed. In this study, we focused on a mechanical investigation in peeling method. Therefore we did computational studies to see how the stress concentration occurred, and at the same time we led some experiments to compare the results and validate the mechanism.

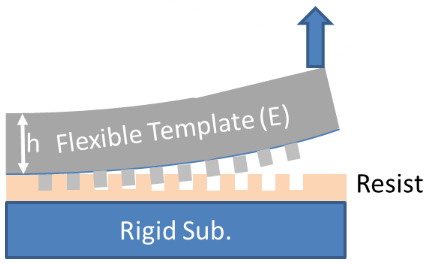
Computational study for peeling release

To investigate peeling release, numerical simulations are approached using conventional finite element method. Figure 1 (a) shows the schematics. We modeled a template with line features having an aspect ratio of 1.0 and the template is lifted up at the edge. The resist is considered separated from the template interface when the applied normal and sheer force exceeds critical value[1)]. We evaluated release force and induced stress in various stiffness of template. Figures 1 b) and c) show simulated results for release force and maximum induced stress. It appears that when the template stiffness decreases the maximum release force decreases too, however the opposite effect is observed on the induced stress. For soft template, the release force decreases because template bending radius area becomes small and total force decreases, however the induced stress in the resist increases due to large template bending.

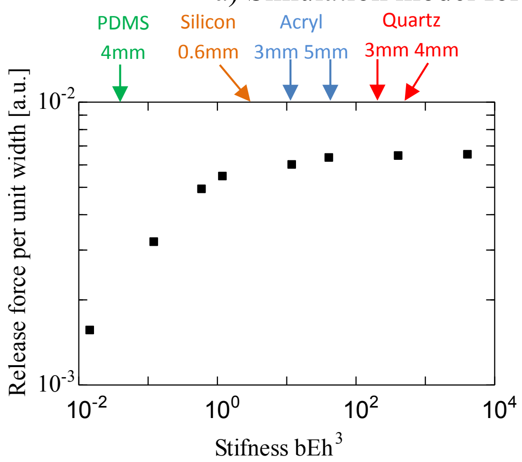
Experiment and discussions

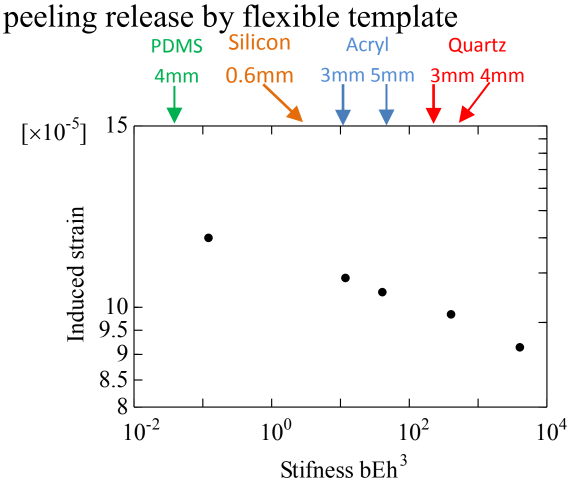
The experimental setup is shown Fig.2. The resist is glued on thin quartz or acryl plate of variable thickness, the silicon template is fixed and an actuator pushes the plate up at the extremity, leading to the release. The releasing force applied by the actuator is measured and SEM observations of the resist after the process allow us to extract the defect rate for the deferent substrates used. We conducted experiments for template thickness of 1mm to 4mm and observed the results on areas of aspect ratio 2, 5 and 10. According to the trends obtained by simulation, a more rigid template should result in fewer defects due to the lower stress induced in the resist. The SEM observations of the resist after peeling experiments are in accordance with this theory because the defect ratio calculated also decreased when we used a more rigid template. The results are consistent to the computational works. As a result, optimization of template stiffness by adjusting thickness for example is required regarding the resist critical strain in order to reduce defects.

Reference
1) T. Shiotsu, et al., J. Vac. Sci. Technol B, 31 (2013) 06FB07.



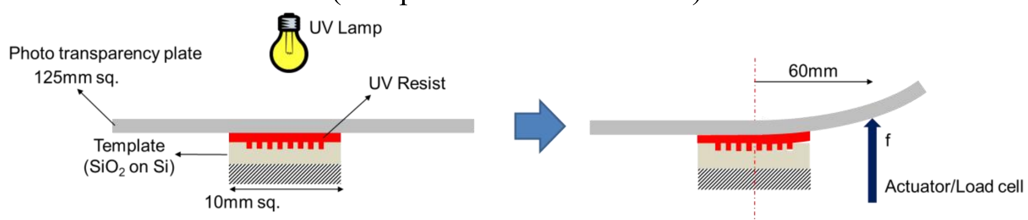
a) Simulation model for peeling release by flexible template



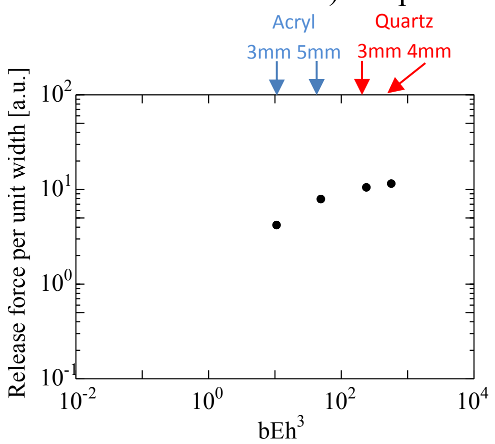


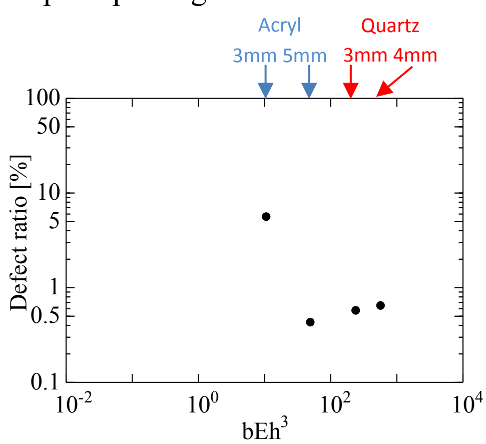
b) Release force per unit length c) Induced maximum strain in resist

Figure 1 Simulation results for flexible template releasing for PMMA resist. (Template width: b=125mm)



a) Experimental setup for peeling release





b) Release force c) Defect ratio for pillar patterns

Figure 2 Experimental results for peel release. (Resist: NICT (Daisel), b=125mm)
Instead of template, flexible plate is used as substrate.