Study on De-molding Kinetics of Peeling and Perpendicular Releasing in NIL process

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Introduction

Mold releasing process in nanoimprint lithography is one of the most essential issues for successful process and several anti-sticking materials, templates, and equipment for successful de-molding have been reported [1-3]. Nevertheless, the approaches are not always generalized in quantitative point of view. Houle[4] and Garidel[5] reported theoretical quantitative inspections of the releasing properties based on Obreimoff's aproach[6]. Moreover, Landis[7] discusses on nano patterned mold releasing and characterizes both friction and adhesion foresees based on the fracture kinetics.

In this report, the deference of mold releasing mode between peeling and perpendicular releasing is experimentally studied and theoretically investigated for resist-mold adhesion.

Experiment

Figure 1 shows schematics of the experimental systems. The UV resist is spun coated on Si substrate and flat quartz template is pressed on the resist. After irradiation of UV light, the bot edges of the template are lifted up using rods as illustrated in Fig.1-a). The rods are controlled to keep parallel and the template is perpendicularly released as much as possible. The loads are measured by load cells and the displacement of the template is measured by optical Interference sensor. On the other hand, the template is lifted up by single rod to peel the template and the resist interface as shown in Fig.1-b). Using this equipment, peeling and perpendicular releasing are investigated.

Both releasing modes are examined using conventional UV resist (PAK01, Toyo Gosei) for two ways of template thicknesses (h=2.0mm and 6.3mm).

Result and discussion

Fig.2 shows experimental results of the releasing force and the template displacement due to bending for 2.0mm thick and 6.3mm thick templates. In this case, anti-sticking layers are not coated on the templates. The releasing forces in the perpendicular releasing mode are almost five to ten times than that of the peeling modes. It is over 10 times in case of rigid template (thick template: h=6.3mm). This is because stress concentration at the resist-template crack front is induced in the peeling mode, however the outbreak of cracks are suppressed in the perpendicular releasing mode.

To confirm it, surface energy γ is estimated based on Obreimoff's [6] approach. The surface energy between resist and template expressed as $\gamma = 3Eh^3\delta^2/16(l+c)^4$, where E, h, δ l, and c are Young's modulus of template, thickness of template, displacement by bending, length of bending, and length of crack (Si substrate), respectively. Acceding to this, γ are estimated over 600mJ/m^2 without anti-sticking treatment on template and around 230mJ/m^2 with anti-sticking layer, respectively. On the centrally, detachment forces could not fit to the Obreimoff's approach based on the fracture theory.

In summary, two different template releasing modes are approached. Using the peeling mode, the templates are released by lower load and the phenomena is characterized by fracture theory. On the other hand, large releasing load are required in the perpendicular releasing mode in rigid systems.

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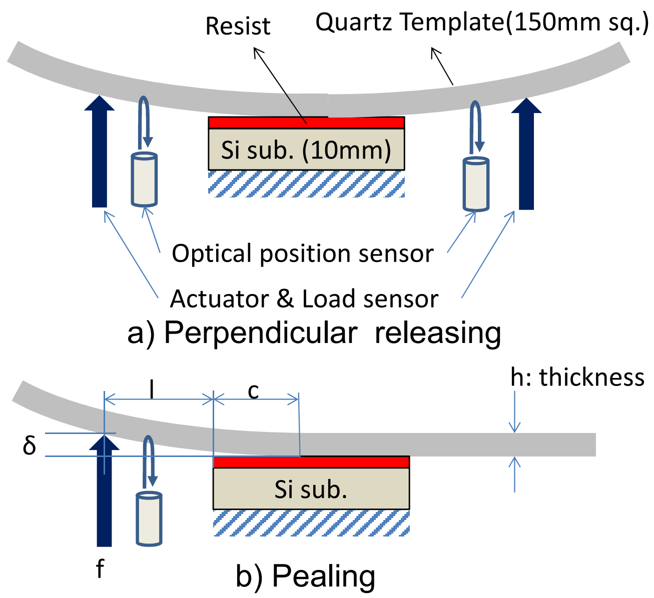

Fig.1. Schematics of experiments

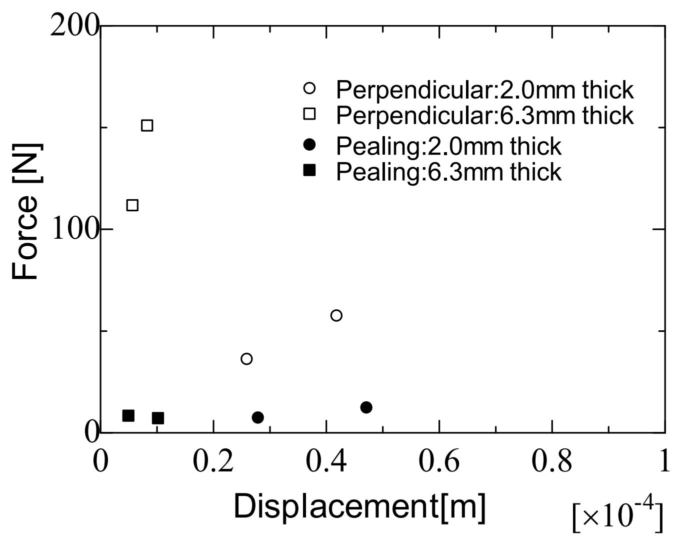

Fig.2. Relation between displacement and detachment force. (without surface treatment on quartz mold)