Impact of Wafer Deformation on Demolding Force for Thermal Imprint Process

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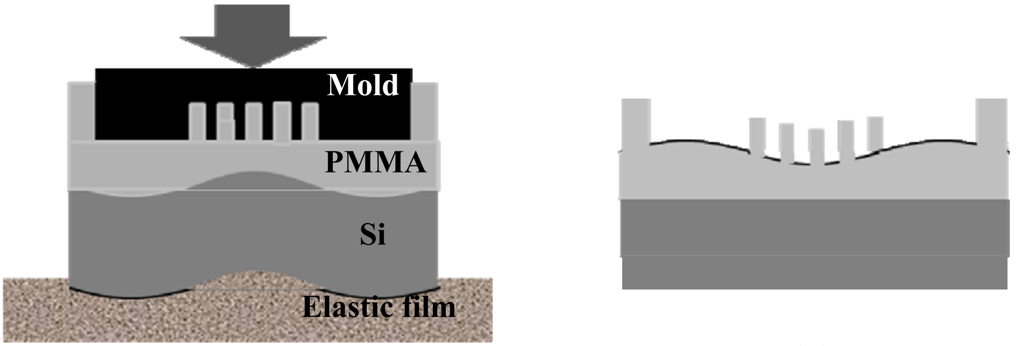
Demolding is one of the most important issues in nanoimprint lithography. It is important to reduce demolding force for successful imprint process. Demolding force is the results of many factors such as adhesion, resist shrinkage and wafer deformation. In this report the effect of wafer deformation is studied. The effect of wafer deformation on the demolding force is explained by using Fig. 1. During the press the Si substrate is deformed by the applied pressure. Since mold patterns go into PMMA under the press pressure, mold patterns are vertically put into the PMMA film on the deformed Si substrate (Fig.1(a)). When the press pressure is removed, the Si wafer recovers the flat surface and the PMMA surface is deformed as shown in Fig.1(b). Then, side walls of the mold cavity are pressed by the PMMA film because they are not vertical to the PMMA film surface.

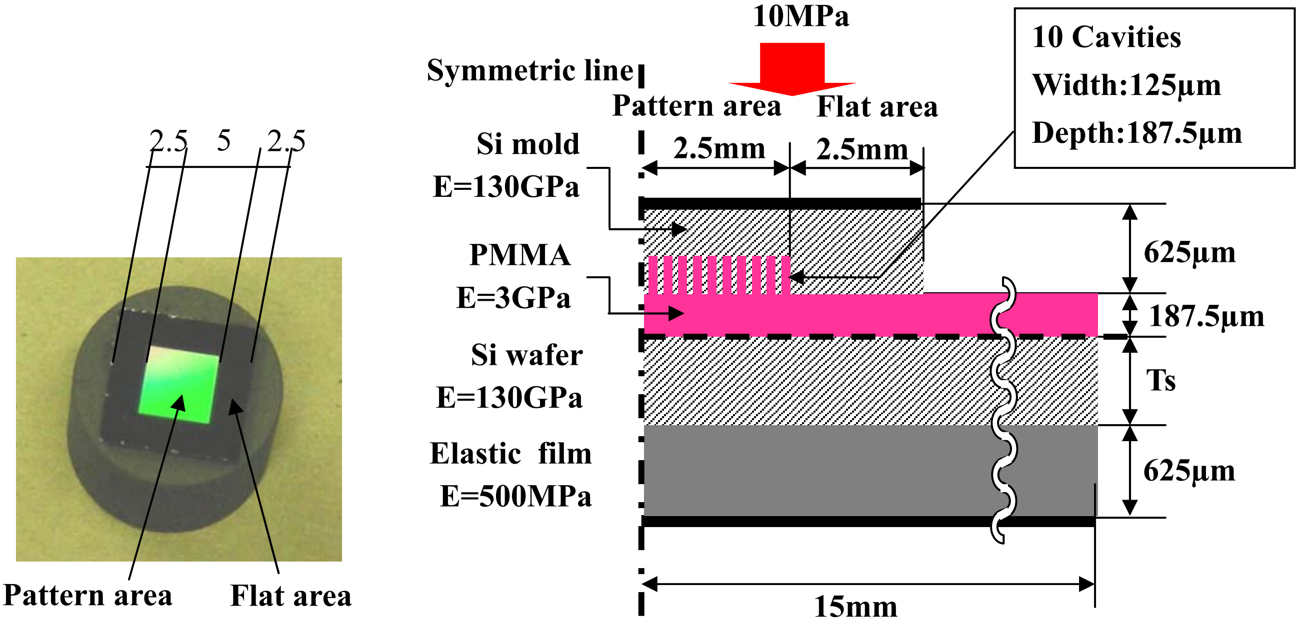
(110) Si wafer of 10 × 10 mm square is used as the mold substrate. Cavity patterns with vertical and very smooth side wall are fabricated in 5 × 5 mm square region by the KOH anisotropic etching. The cavity width and depth are 2 μm and 3 μm, respectively. The Si mold is shown in Fig. 2(a). The mold is pressed to 5 μm thick PMMA film on Si wafer of 30 × 30 mm square. Three Si wafers with Ts = 200 μm, 625μm and 1000μm thicknesses are used. The press conditions are 170ºC, 10MPa for 15 min and the press pressure is kept during the cooling. The 30 × 30 mm Si wafer deformation is calculated by FEM simulation. The model for the simulation is shown in Fig. 2(b). Although the cavity size and the PMMA film thickness in the simulation are much larger than those in the experiment, the deformation effect can be fairly shown. The wafer deformations by the simulation are shown in Fig. 3(a). The vertical extent of the deformation is small and the lateral extent of the deformation area is extended to the pattern area for Ts=1000 μm. On the other hand the deformation area is not extended to the pattern area for Ts=200 μm. The wafer deformation can be roughly estimated by the step height measurement [1]. The results are shown in Fig. 3(b). The experimental results agree to the simulation ones. The total press force to the mold cavity side wall by PMMA resin is obtained by the simulation. They are shown in Fig. 4. The demolding forces by the experiment are also shown in the figure. These values for Ts=1000 μm are larger than those for Ts=200 μm because the deformation in the pattern area for Ts=1000 μm is more obvious. It is confirmed that the demolding force is strongly related to the mold deformation in the pattern area.

[1] H. Kawata, et al., to be accepted in Jpn. J. Appl. Phys.



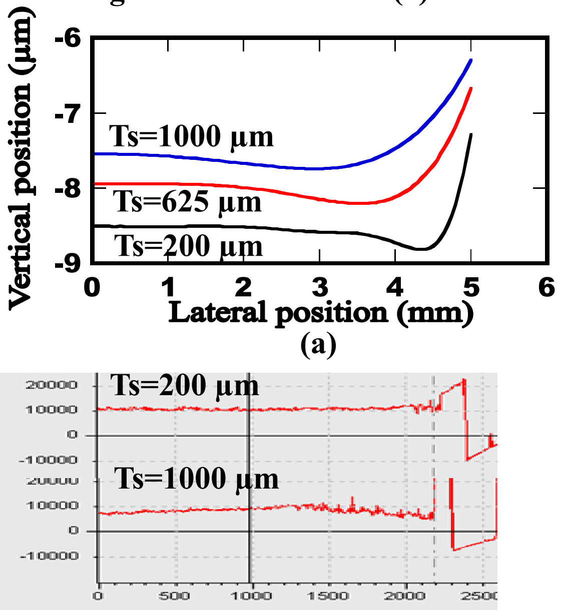
(a) (b)

Fig.1 Illustrations of deformation, (a) during press, (b) after press.



(a) (b)

Fig.2 Mold structures. (a) used mold in experiment, (b) simulation model



(b)

Fig.3 Lateral dependence of deformation, (a) simulation, (b) experimrnt

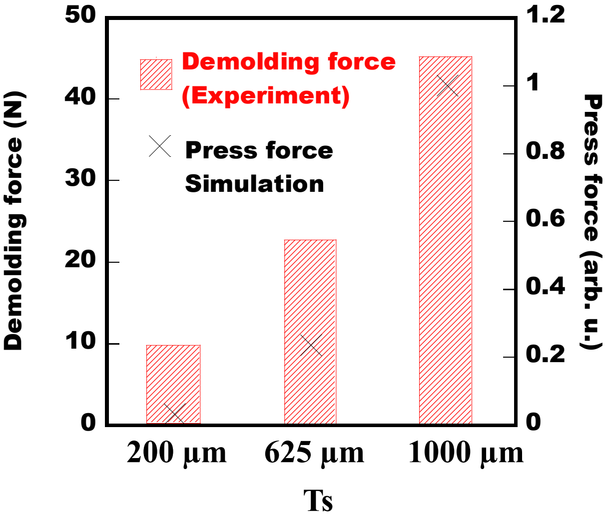


Fig.4 Demolding force by experiment and press force by simulation for various Si wafer thicknesses.