Comparison of Demolding Forces for Various Si Molds and Mold with Extremely Smooth Side Wall

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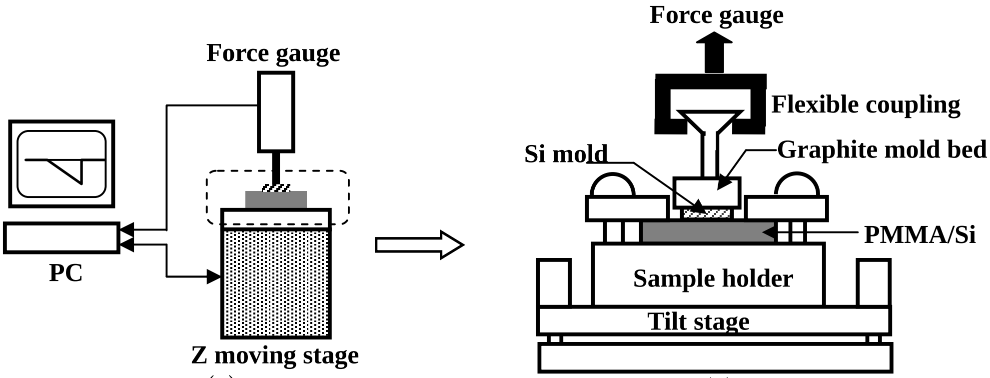
Demolding is one of the most important issues in nanoimprint lithography. Although molds with smooth side wall are desired, it is impossible to fabricate a mold with perfect smooth side wall. It is important to compare the demolding forces with the used mold and the mold with very smooth side wall. In this report silicon mold with extremely smooth side wall is fabricated by the anisotropic etching by KOH, and the demolding forces are measured for both Si molds by plasma etching and by the KOH anisotropic etching

Si wafer with approximately 100 mm^2 size is used for mold. Line and space pattern of 2 μm half pitch are fabricated in a circle region of 5 mm diameter. Three molds are fabricated by different processes. The improved alternate plasma etching process is used in order to suppress the side wall scalloping(1) (Mold A). The Si wafer after the plasma etching process is dipped into the mixed solution of 1.5 Mole/L KOH solution and isopropyl alcohol in order to reduce the scalloping(2) (Mold B). (110) Si wafer is etched by 5 Mole/L KOH solution for 5 min at 65°C (Mold C). Vertical side wall with (111) orientation can be obtained. After the SAM treatment, the mold is pressed to a PMMA film of 5 μm thick on Si wafer. The press conditions are 160ºC, 10MPa for 15 min. The demolding forces are measured by the measurement system shown in Fig. 1.

The SEM pictures of the molds are shown in Fig. 2. Both the cavity depth, D, and the side wall roughness, R, are also shown. Small scalloping can be observed for both the Mold A and the Mold B. Extremely smooth side wall can be obtained for the Mold C. The PMMA patterns are shown in Fig. 3. The PMMA patterns can be successfully fabricated in the whole patterned area for all the molds. The demolding forces are shown in Fig. 4. The demolding force is defined as the measured force divided by the total side wall area, because it is considered that the demolding force greatly depends on the side wall condition. It is seen that the demolding force can be decreased by decreasing the side wall roughness. When the flat mold, where no pattern is fabricated on the mold surface, is used, the demolding force is smaller than the measurable force for our system(3). Note that the demolding force remains for the Mold C. This shows that the demolding force is controlled by the side wall even when the mold with extremely smooth side wall is used.

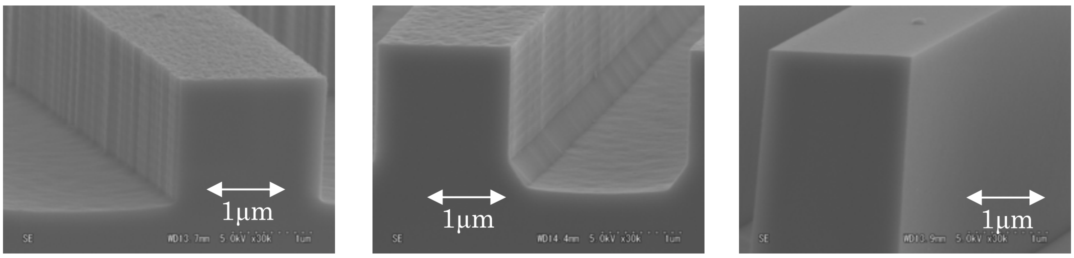
(1) H. Kawata, et al., Microelectron. Eng., **84**, 1140 (2007).
(2) H. Kawata, et al., Microelectron. Eng., in press.
(3) J. Ishihara, et al., Digest of Papers of MNC 2007 (Kyoto, Japan ,2007) p.450.



(a) (b)

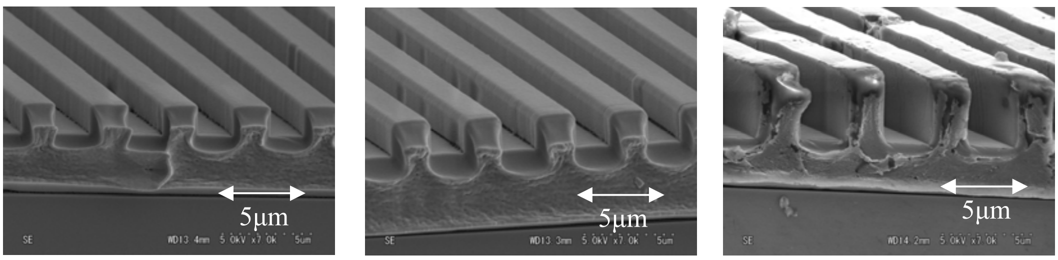
Fig. 1 System for demolding force measurement. (a) Total view, (b) Around sample.

Mold A Mold B Mold C



D=1.8 μm, R=20 nm D=1.9 μm, R=10 nm D=3.4 μm, R<10 nm

Fig. 2 SEM pictures of the used molds.



(a) (b) (c)

Fig. 3 SEM pictures of PMMA patterns. (a), (b), (c) correspond to results for Mold A, Mold B, Mold C, respectively

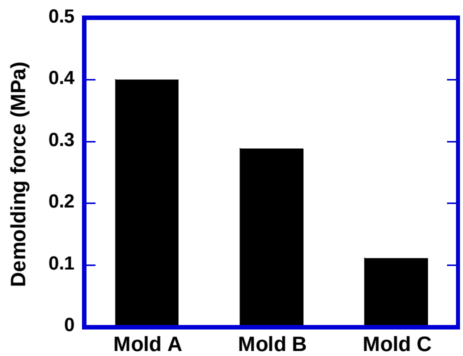


Fig. 4 Demolding force (=(Measurement force)/(Total side wall area)) for the fabricated molds.