THE USE OF AUTOMATIC DEMOLDING ON NANOIMPRINT LITHOGRAPHY PROCESSES

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In nanoimprint lithography one of the critical issues is the pattern transfer between the stamp and the polymer, in which the demolding plays a fundamental role. During demolding, the mold is separated from the embossed polymer structure by a vertical movement of the stamp. Distortion or damaging of the molded structure during this movement can occur as a result of different effects such as adhesion at the surface, friction due to surface roughness and trapping of the polymer due to negative slopes of cavity sidewalls. As a result the polymer structures or parts of the wall profile are either ripped away or deformed during demolding [1]. This fact increases drastically with high aspect ratio structures as well as low molecular weight [2]. This work studies the importance of two different automatic demolding processes carried out in the HEX03 machine from Jenoptik in function of the line width, aspect-ratio and molecular weight of the PMMA imprinted.

Silicon wafers with 1 mm thickness and 100 mm diameter were used as stamps. Stamps constituted by micro-features with five different gratings (fig 1a) were fabricated by UV-Lithography and dry etching process in SF_6 and C_4F_8 to get 420 nm depth. The wafers with nano-features among 125 nm and 800 nm (fig 1b) were firstly coated with 50 nm of SiO_2 and patterned by e-beam lithography. The patterns in the resist was transferred into oxide layer by dry etching in CF_4/CHF_3/He plasma and then transferred into silicon by Cl_2/He plasma to reach a final trench depth of 500 nm (fig 1c). Under this design, aspect-ratios up to 0.28 and 4 were reached respectively. Both stamps were anodically bonded to a pyrex wafer and coated with an antiadhesive layer coating based on silane chemistry (F_{13}-TCS). The stacks were mechanically fixed to a tool holder (fig 2) and placed at the top side of the press machine.

The first setup for automatic demolding uses the air supported demolding facility of the HEX03. This setup was used on 6” silicon wafers coated with 500 nm of mr-IPMMA with molecular weight 35k, 75k, 120k. 4” silicon stamps with microstructures and nanostructures were used. During demolding, as tool and substrate move apart at low speed, the pressurized air acts as demolding pressure at the marginal areas of the substrate. As tool and substrate move further apart, the pressurized air is applied to a continuously increasing area of the substrate until the substrate is completely demolded. This process was run successfully on both stamps and substrate and stamp were rightly separated, keeping the stamp and the substrate at the top and at the bottom of the chamber respectively in all the studied processes. No differences were observed as micro-stamp is embossed on different molecular weights or as the stamp is embossed in a press mode and both wafers are separated manually. However, important differences were observed on the nanoscale in function of the molecular weight and imprinting mode. If conventional press mode is used, at the mold releasing process, the stress is concentrated near the base area of the polymer pattern and the polymer is fractured for 125, 200 and 400 nm lines for all the molecular weights checked (fig 3a). As demolding induced by air is used, this effect is not observed (fig 3b) for 200 and 400 nm lines. 125 nm lines are cracked with this automatic demolding setup too, even the density of cracking lines is much lower. Figure 4a and 4b shows a comparison between automatic demolding processes with 35k and 120k, in which minor cracking can be seen on this last one. It may be justified by the fact that 35k is more brittle below T_g, leading easier to the cracking of the smallest lines. An alternative automatic demolding based on a fast separation movement between a non clamped substrate and a clamped stamp was used based on a fast releasing between stamp and substrate. In this way, the adhesion force between PDMS (compliance layer used) and substrate acts like an uniform demolding force. This process works right for micro-features and even up to 400 nm lines. However the

125 and 200 nm lines are deformed and elongated up to more than 600 nm in height (figure 4c) showing cracking as well on the smallest ones.

References

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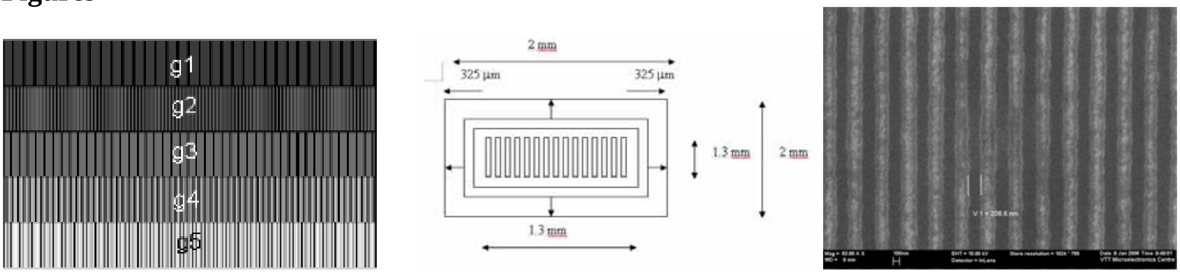
Figures



a) b) c)

Figure 1. a) Diferent grating periods fabricated. g_1 period=11.3 μm, g_2=10 μm, g_3=6.6 μm, g_4=5.2 μm, g_5=3.3 μm. Total length=20 millimeters, each line length=4 millimeters. Six different total units repeated through the 4" silicon stamp. b) Different grating periods fabricated. Each unity is repeated through 4" silicon wafer with line width of 125 nm, 200 nm, 400 nm, 600 nm and 800 nm. c) Stamps fabricated on silicon with 200 nm line width.

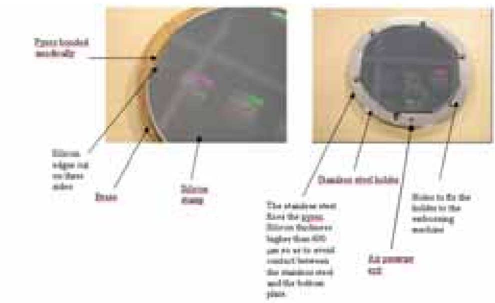
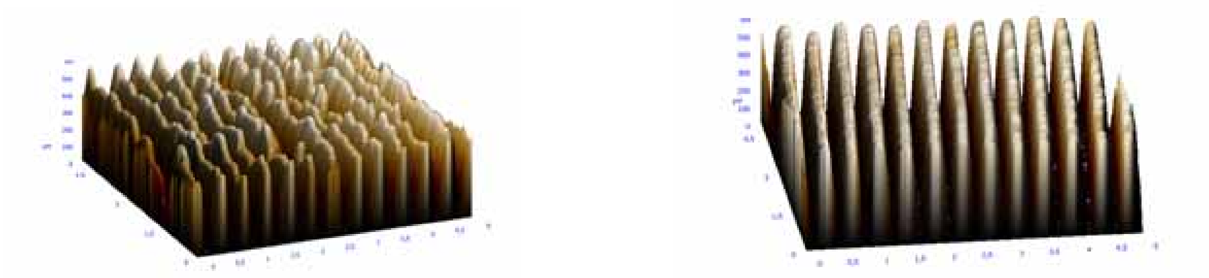


Figure 2. Description of the tool used for automatic demolding.



a) b)

Figure 3. a) AFM topography showing the partial cracking on 200 nm lines (AR=2.5) in a press mode imprinting on PMMA75k. b) AFM topography showing the same imprinted sample on 200 nm lines in automatic demolding induced by air. This fact is repeated through the whole of the wafer.

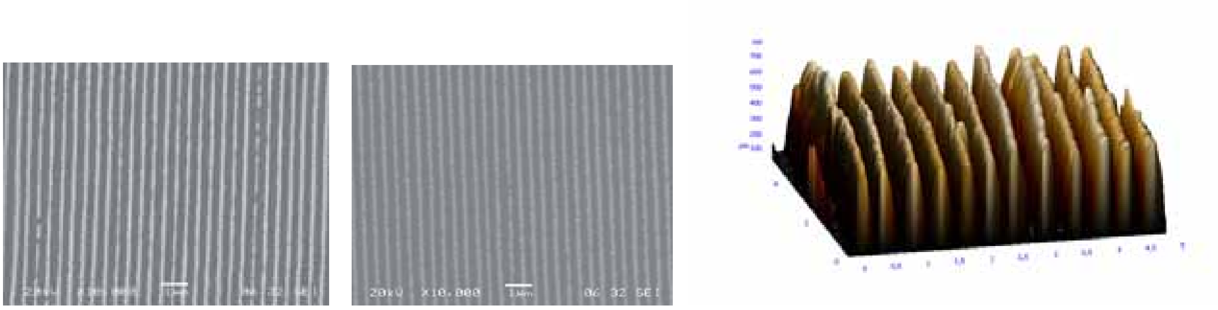


Figure 4. a) SEM picture showing the 200 nm lines imprinted in PMMA35k using automatic demolding induced by air. b) SEM picture showing the 200 nm lines imprinted in PMMA120K using automatic demolding induced by air. c) AFM topography showing the deformation of the 200 nm lines as demolding induced by gluing and high demolding speed is used.

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