Anisotropic filling phenomenon of trenches in UV nanoimprint

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Resist filling process of mold cavities is an important step of transferring patterns in nanoimprint. The filling process directly affects the pattern transfer fidelity and the process throughput. Incomplete filling results in void defects in the imprinted samples and the process time has to be longer for preventing the defects. To understand the filling process, many efforts have been made using experimental methods and numerical simulations. [1] It is well reported that the resist expands under the imprint pressure and isotropically flows into the cavities of a mold from all directions. [2] However, this understanding should be re-examined in fabricating complex 3D patterns used for special functions. In this paper, we report an anisotropic filling phenomenon of trenches in UV nanoimprint.

As an example of a 3D complex pattern, we fabricated a mold made of quartz with a step structure as shown in Fig. 1. Line trenches were first etched to the depth of 90 nm, and then deep cavities of 270 nm were made in the line trenches patterns as a model structure of a capacity-equalized mold. [3] The resin used in the nanoimprint experiments was a UV photo-curable resin at the thickness of 80 nm spin-coated on a silicon wafer, UV nanoimprint was carried out in pentafluoropropane environment.

To investigate the filling process of cavities, bubble elimination process was recorded using a direct monitoring video system, and the bubbles entrapped in the cavities were tracked. The bubble shape variation in the filling process of cavities with lengths of 62.5μm and 125μm in the mold under the imprint pressure of 0.5MPa is shown in Fig 2. It can be clearly noticed that the bubbles mainly shrank along the trench direction, especially at the beginning. Using the bubble sizes determined from the images captured in the recorded video of the filling process at intervals of 0.1s, a relationship of bubble dimension variation with the resist filling time of a cavity in a mold is shown in Fig. 3. Contrary to the prediction that the bubbles would shrink isotropically in the directions along and vertical to the line pattern [2], we found an anisotropic filling phenomenon of cavities, i.e. the bubbles shrank mainly along the directions of the line pattern trench. Different with the well-reported isotropic filling process, this process shown in Figs. 2 and 3 was anisotropic. With the decrease of the bubble length, the bubbles gradually changed their shapes and finally the difference of length and width of bubbles vanished. From this point, bubbles shrank almost the same in the direction of length and width. This means the filling process changed to be isotropic again till the disappearance of bubbles.

From our study, we can predict that filling process of the other 3D complex patterns should have similar two-phase filling processes: an anisotropic filling process in the first filling period, and an isotropic filling process following the anisotropic one. This will provide a guideline on how to prevent imcomplete filling while keeping a high throughput nanoimprint process.

References

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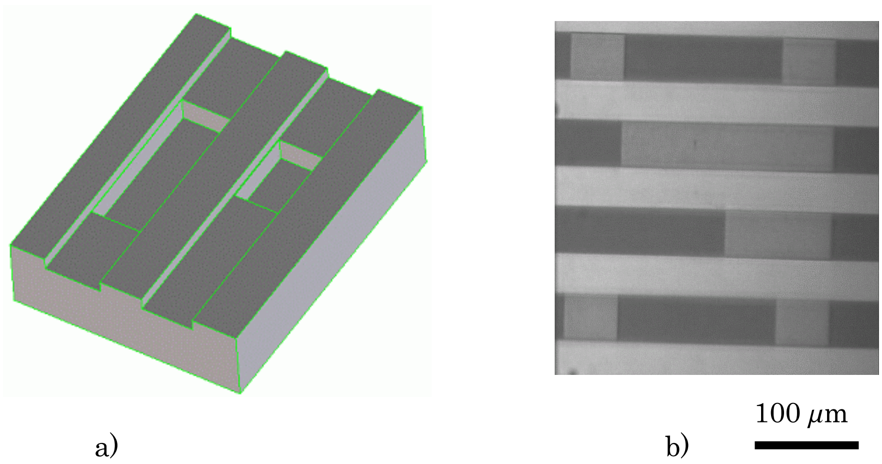

Fig. 1 a) Schematic and b) top view of a mold with cavities in trenches

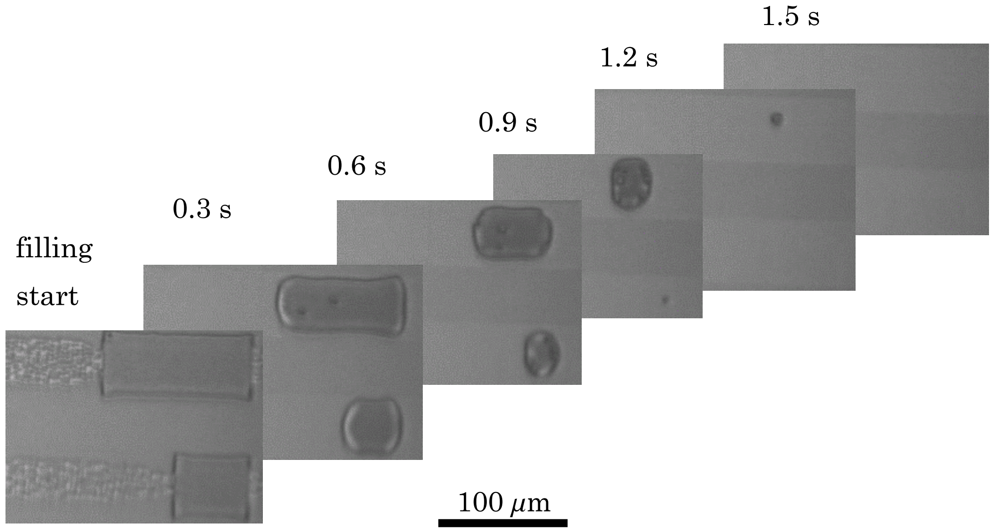

Fig. 2 Filling process of cavities with lengths of 62.5μm and 125μm in the mold(0.5MPa)

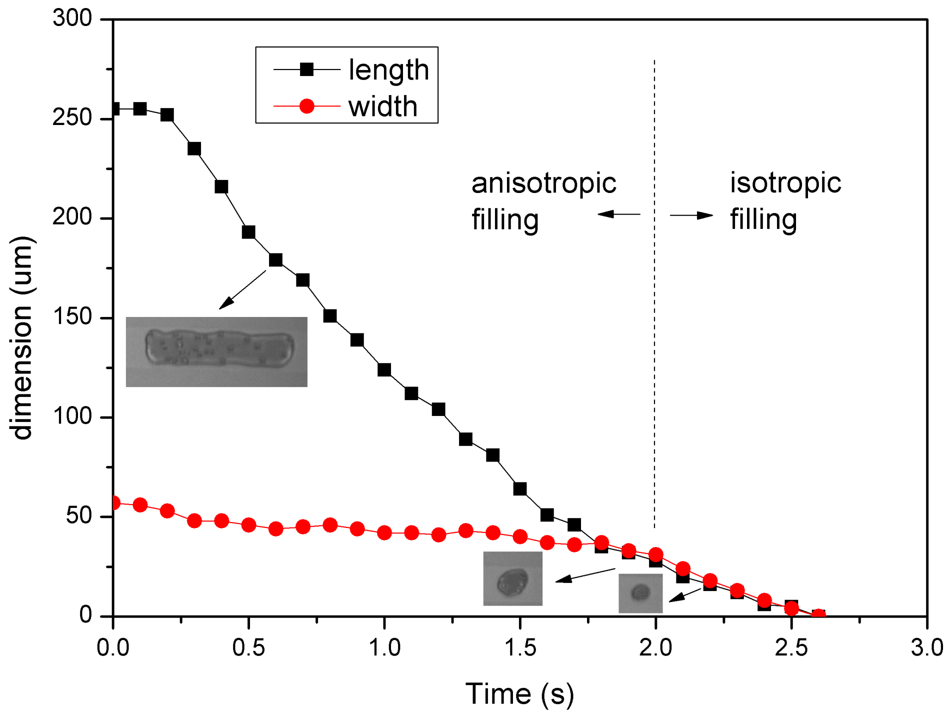

Fig. 3 Bubble dimension variation with the resist filling time of a cavity in a mold