The fabrication of 3D and multilevel molds for UV curable nanoimprint by using variable electron beam dose controlled exposure

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Recently, three-dimensional (3D) nanoimprint lithography (NIL) has attracted significant interest for use in a number of applications including microfluidic devices, micro-optics, biochemistry and microsystems. Some complicated designs require 3D structures with multilevel to eliminate multiple process steps and complex alignments. Despite NIL technology has demonstrated 3D and multilevel patterning with a single step process[1,2], the mold fabrication is still the major challenge. We have developed a process for making 3D structures with multilevel features in a simple two steps process as illustrated in Figure 1.

The 3D mold profiles are created on the negative tone photoresist using the Raith150 electron beam lithography (EBL) tool with variable dose controlled exposure in a single step exposure. A linear resist contrast profile has been obtained with a negative tone photoresist from Microresist, ma-N2403 and subsequently have been utilised as the 3D masking layer. The 3D patterns have been transferred into the mold substrates by single step reactive ion etching (RIE) with suitable resist selectivity to mold substrate.

In this work, a pyramidal structure array in two different levels, have been chosen as an example of the test pattern to demonstrate the ability to create the 3D structure with multilevel requirements. The intended pyramid structures are about 1 micron square base and half microns in height. Top level is about half microns higher than lower level. The precision of the fabricated structures is highly important especially for microoptics devices. The differences between intended and final dimension and the surface roughness of the structures' surface are also analysed.

Figure 2 shows the 3D profiles of the developed photoresist on the Silicon substrate as the 3D masking layer while Figure 3 shows the final structure transferred onto the Silicon mold. The Silicon and Quartz have been chosen as the materials for the master molds. The process capabilities of these two different substrate materials for 3D mold structures have also been studied.

By using this technique, the complex structures required for 3D molds can be achieved with single step of electron beam exposure and single step of dry etching process.

[1] M. Konijn, M. M. Alkaisi, R. J. Blaikie, ''Nanoimprint lithography of sub-100 nm 3D structures'', Microelectronic Engineering, 78-79, pp653-658, 2005.

[2] M. M. Alkaisi, W. Jayatissa, M. Konijn, ''Multilevel nanoimprint lithography '', Current Applied Physics 4, pp111-114, 2004.

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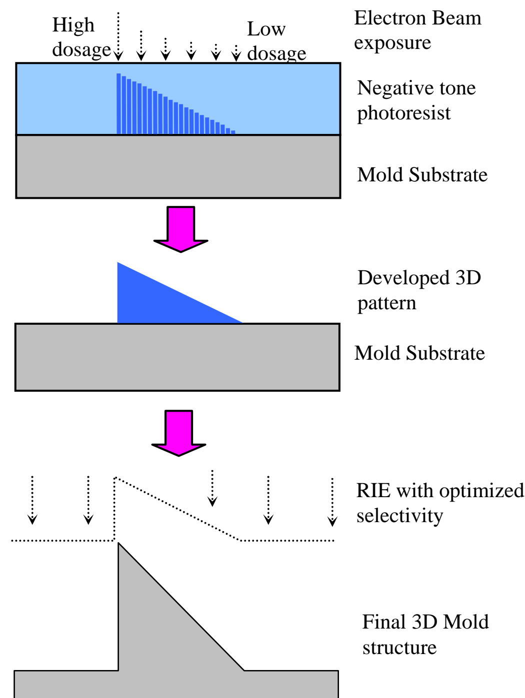

Figure 1: The process of developing the 3D pattern as a masking layer and the optimization of the RIE process for suitable selectivity to achieve intended final dimension of 3D mold structures.

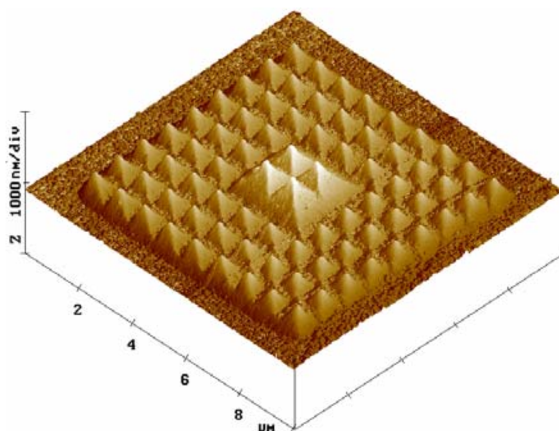

Figure 2 : The AFM image of the developed 3D and multilevel structure on the negative tone photoresist. It shows the similar pyramid arrays at two different levels. The height of the lower level pyramid array was about 250nm and the centre pyramid array was raised about 250nm from lower level

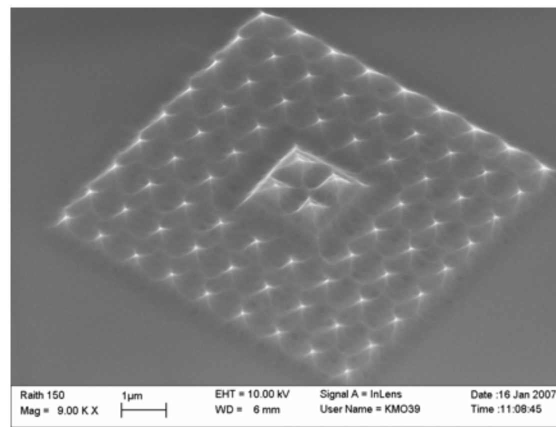

Figure 3: The SEM image of the final 3D and multilevel structure after the pattern transfer process by RIE.