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A Note on Fabrication of Nano Mold for Nanoimprint Lithography

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ABSTRACT

In order to create inversed patterns, nanoimprint lithography applies nanomolds to resists. It may be used to quickly and cheaply produce high resolution nanopatterns on both curved and flat surfaces. The quality of the nanoimprinted features depends on how faithfully the manufactured master nanopatterns and elastomer nanomolds are made. Despite extensive study into two-dimensional nanoimprint lithography, nothing is known about three-dimensional master nanopatterns and nanomolds. Even fewer of them talked about the consistency of complete processes from the creation of the original master to the final nanoimprinting. With the help of an atomic force microscope (AFM) and ultrasonic vibration assisted nanomachining, we were able to create three-dimensional master nanopatterns with intricate curves and constant height changes, as we showed in this paper. Using nanomolds the creation of the master nanopatterns with a positive draught, which comes naturally from the AFM tip, nanomolds for nanoimprint lithography were created. We looked into the accuracy of the outcomes produced by nanomachining and the aftereffects of recycling material patterns. Additionally, we showed that the solvent-assisted microcontact moulding process is capable of 3D nanoimprinting, and we found a way to adjust the layer-thickness of imprinted 3D nanopatterns.

INTRODUCTION

Recently, scalable nanofabrication methods that have the potential for mass production have received a lot of attention. One of the most promising technologies for creating large-area, extremely high-resolution, flexible nanopatterns with cheap cost and high efficiency is nanoimprint lithography (NIL). Along with two-dimensional nanopatterning techniques, three-dimensional (3D) NIL techniques have also recently received more attention because 3D nanopatterns are currently being studied and used in numerous fields, including biosensing, optics, and plasmonics. The main building blocks used to create daughter moulds or reverse patterns for the 3D NIL are 3D master nanopatterns. In general, two methods of creating 3D master nanopatterns are direct writing and mask patterning. Both one-time and multi-time patternings have been studied for mask-involved patterning approaches. As an illustration, 3D nanocones were created. For instance, to create extremely sensitive surface enhanced Raman spectroscopy (SERS) substrates, 3D nanocones were first created using one-time reactive ion etching (RIE) using masks. A sequence of lithography rounds and subsequent etching rounds produced high-resolution 3D nanopatterns with good surface roughness. Mask patterning techniques are only capable of creating discrete heights patterns, despite being able to pattern vast regions [1]. Despite their value, they are still not as flexible as maskless patterning methods, which may produce intricate patterns with unlimited forms and continuous heights. Technologies for maskless nanopatterning have been researched for use in three dimensions. Focused ion beam lithography (FIBL) and electron beam lithography (EBL) are the representing tools (FIB). By manipulating the power of the EBL, for instance, sub-100-nm 3D moulds for NIL were created, and some RIE in a single step. However, the scattering of electrons in resists reduces the quality of the 3D patterns created by EBL. FIB has been utilised to create 3D nanotemplates because it has more sensitivity, faster patterning, and less forward scattering than EBL. However, just like with EBL, adopting FIB is expensive [2].

METHOD

3D nanomolds must be produced in an economical manner in order to use nanoimprint lithography for scalable manufacturing. AFM-based maskless 3D nanopatterning methods, including as thermally induced 3D nanopatterning, direct mechanical scratching, and ultrasonic vibration assisted nanomachining, have been researched as a less expensive alternative. The created nanostructures can also be employed as the 3D NIL's material patterns. This study examines inexpensive 3D nanomolds. Employing AFM-based ultrasonic vibration assisted nanomachining to fabricate for NIL. It was examined and determined whether the manufactured master patterns were faithful. Based on master designs, flexible reverse nanomolds were created. After repeatedly creating many daughter moulds, the master nanopatterns were examined to determine

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the dimension changes. NIL was used to create nanoimprinted designs using the 3D nanomolds [3]. Master nanopatterns are required for 3D nanoimprint lithography processes to reverse-fabricate daughter moulds, or 3D nanomolds. Then, in the next steps, the 3D nanomolds can be used to perform 3D nanoimprint lithography using either the solvent- aided microcontact moulding (SAMIM) technique or the ultraviolet nanoimprint lithography (UV-NIL) procedure. Shows the steps involved in the complete 3D nanoimprint lithography process, starting with the creation of master nanopatterns using an AFM-based 3D nanomachining technique and ending with imprinting and demolding. The first step is to set up a sample on a silicon substrate with a layer of spin-coated polymethyl methacrylate (PMMA) thin film. A4 950 PMMA coated film was used [4]. PMMA solution was applied to the silicon surface and then spin-coated for 40 seconds at 4000 RPM by The anisole solvent was then removed from the sample by baking it for 90 seconds at 180 °C. After completing, the sample was covered with a 200 nm thick layer of PMMA film with a 0.8 nm surface roughness.

RESULTS

The master nanopatterns serve as the 3D nanoimprint lithography's templates. The reversely printed nanomolds' quality and the subsequent processes are determined by the faithfulness. To create 3D nanopatterns that are simple to deform and have a good surface quality, the fabrication method used for the master patterns is essential. exemplifies the qualities of master patterns that are simple to demold. Similar to the conventional casting process, a positive draught angle speeds up demolding and lowers fault rates in 3D nanomolds with reversely printed surfaces. AFM-based ultrasonic vibration assisted nanomachining is particularly suitable for creating master patterns with positive draught angles that are easy to demold [5]. To show off the potential of AFM-based ultrasonic vibration assisted nanomachining for 3D nanoimprint lithography, four identical three-layer nanostructures are created. From top to bottom, the layer thicknesses are 40 nm, 23 nm, and 23 nm, which are nearly the intended 40 nm, 25 nm, and 25 nm. The actual pattern depth is 2–6 nm shorter than the planned depth of 90 nm, at 84–88 nm. After nanomachining, the surface roughness (Ra) is reduced to a value between 0.9 and 1.1 nm.

DISCUSSIONS

The three-layer nanomolds' layer thicknesses and overall height are comparable to those of the master patterns, but their corner radius is greater than that of the master patterns. The missing material during the demolding process can be the cause of the rounded corners [6]. The surface roughness (Ra) after moulding is in the range of 0.7-0.9 nm, indicating that the PDMS moulds have better surface roughness than the master patterns and have become nearly as abrasive as the spin-coated PMMA surface. It proved we were able to create master designs and PDMS reverse moulds with intricate contours and constant height variations. Understanding the reverse moulding stick effect, the reusability of the PMMA mould, and the rounded corner investigated. The outcomes following three repetitions of the same PMMA master patterns. the master patterns in sequence following each use. the master pattern dimensions being compared. Before any reverse moulding, four cross-sectional profiles from the original master design were nanomachined before being aligned together, and three profiles were moulded once, twice, and three times sequentially. When comparing the original and cast master profiles, we can see that the depths were similar but that the top and second layer's sharp corner had been slightly smoothed. The PMMA master nanopatterns' rather sharp corners between layers rounded off when more reversed PDMS was created. When more fresh PDMS moulds are patterned, it means there will be more leftover PDMS left on the PMMA surface, especially in the corner locations. Three mouldings resulted in a 15 nm total depth reduction and a considerable loss of layer thickness and corner shape accuracy. The stick effect brought on by the PMMA master pattern may be remedied in some ways. First, a self-assembled monolayer is coated with trichloro silane [7].

CONCLUSION

This makes it easier for the PDMS to resist adhesion. Alternately, we can use RIE to first transfer the master patterns onto the silicon mould before applying the silane anti-adhesion monolayer. Applying PDMS solvent to the silicon master patterns after each demolding, such as by employing a diluted solution of TBAF (1 percent) in propylene glycol methyl ether acetate, could clean the silicon master patterns even if there are any minute residuals left (PMA). There won't be any lingering corner rounding problems. Results of SAMIM's implementation for 3D nanoimprint lithography Even though the shape and appearance are reasonable, the imprinted features' depths could not reach 80 nm. The volume of acetone may not have been sufficient to adequately mount the PMMA coatings that encircle the projecting pillars, which could be the cause [8]. Or the acetone evaporates quickly, making it impossible for it to dissolve the PMMA quickly and produce deep features. Using different solvents, such as anisole or toluene, which evaporate more slowly, may help the implementation results. that the mould surfaces are more level than the layer surfaces [9]. This can be the result of the manual pressure required to deploy SAMIM. The mechanical force used is the only distinction between the two nanoimprint lithography methods. 20 nm and 40 nm total depths, albeit they did not replicate the reverse forms of the nanomolds suggests that the layer-thickness and overall height of the new imprinted 3D patterns may be tuned using the mechanical force used in 3D nanoimprint lithography. because PDMS is a substance that resembles rubber and is easily distorted by mechanical forces. The outcomes motivate a novel method of PDMS mould utilisation in the 3D nanoimprint lithograph. This study showed how cost-effectively master nanopatterns for 3D nanoimprint lithography may be made using an ultrasonic vibration assisted nanomachining technique based on atomic force microscopy (AFM). From master patterns with complicated shapes and continuous height variations, nanomolds can be reversely patterned. The AFM tip's ability to provide a natural positive draught makes the demolding process easier [10]. If silane anti-adhesion monolayer is not applied, after repeatedly moulding PDMS, residuals will remain in the PMMA master patterns. We showed that the SAMIM 3D nanoimprint lithography method, which has seen little to no research demonstrations, can be employed with 3D PDMS moulds. The imprinting results suggest that varying degrees of mechanical forces may be used to regulate the layer-thickness of new nanostructures [11].

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None

Conflict of Interest

None

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