Micro Patterning Using UV-Nanoimprint Process

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Nanoimprint process is a simple and low cost micro/nano fabrication method based on mold replication principle. UV nanoimprint has capable of high accuracy and precise patterning because of lower press force and lower heat generation process comparing with thermal nanoimprint. Therefore, various kinds of devices required high accuracy patterning such as optical devices, patterned media, electronics and MEMS devices are greatly expected as UV nanoimprint applications. In this paper, our recent progress including tools and replication results on UV nanoimprint is described.

Keywords: Nanoimprint, mold, replication, UV resin, roll to roll, MEMS

1. Introduction

In 1995, Prof. S. Chou et al. demonstrated very attractive nanofabrication process, called as Nanoimprint Lithography (NIL) [1][2], which is capable of nm-order resolution and expected as next generation lithography process for semiconductor fabrication below 32nm feature size [3]. Nanoimprint is simple replication process [4], one of the molding process, to a polymer material using a mold, so that low-cost and mass productive nanofabrication can be realized without expensive fabrication process tools such as an electron beam lithography system or an optical lithography system with short wavelength. Also, 3D microstructures such as curved surface or multi stepped structures are realized at only one process by using the mold consisting of the 3D microstructure. Because nanoimprint process has several advantages comparing with conventional micro/nano fabrication methods especially in cost, there are various potential applications to many fields not only semiconductor devices but also MEMS, micro optics, patterned media, nano-bio devices, and optical films for flat panel display.

UV nanoimprint has the great possibility in replication of extreme precise pattern with high accuracy because lower press force and no heat cycle process is possible. However, there are several technical issues, such as large area uniform replication and throughput improvement, to be solved for industrialization of the process. In this paper, our activities on UV nanoimprint for industrialization will be introduced and originally developed nanoimprint tools, a press type and a roll to roll system, will be described in detail.

2. UV nanoimprint process

Fig. 1 shows a process outline of UV nanoimprint. Replication by UV nanoimprint is carried out the following procedure. Firstly, UV curing resin is deposited or spin coated on a substrate (a). And a quartz mold is approached and contacted to the substrate, and UV resin is filled into the mold by press force to the mold (b). After the filling the resin to the mold, UV light is emitted through the mold and cured the resin (c). Replicated microstructures are completed onto the substrate after releasing the mold from the substrate (d). Treatment of release layer on the mold surface must be necessary to separate the mold and UV resin easily and
Higher throughput process must be required to obtain a good replication. UV nanoimprint process has the advantage of high accuracy replication because of low stress and no heat deformation during the process, so that many kinds application required sub-micron order patterning, as patterned media, micro optical device, electronics devices and so on, could be realized using UV nanoimprint process.

3. Technical issues for industrialization of UV nanoimprint

Fig.2 shows representative application fields of nanoimprint process. Nanoimprint becomes very popular micro/nano fabrication process in R&D stage in the above application fields, however technical issues to be solved to adopt nanoimprint as mass production process are still remaining. Many devices require relatively large area replication, more than 100nm, as shown in Fig.2, so that large area and uniform replication process must be adopted to fabricate the devices. Also, higher throughput process must be required to produce large amount of devices because many of the devices are applied to consumer products. From these points of views, large area and higher throughput nanoimprint process must be developed.

3. Nanoimprint process tool

There are several types in nanoimprint tool, a flat surface press type, a step and repeat type, and a roll press type as shown in Fig. 3. It is important to select the tool type to meet process requirement. Flat surface press type (a) is the most simple and popular way in nanoimprint process. However, some difficulties in large area replication exists because maintaining the press force uniformity in large surface area. Step and repeat type (b), which repeats the press type nanoimprint process onto the substrate in order, is relatively reasonable way to form the microstructure in large area. But the microstructure formed at each step is independent each other, that is formation of seamless microstructure in large size by stitching in each step is basically not available. A roll press type (c), which utilizes a roller as a press mechanism, is the most attractive way to realize a large size microstructure because pressure uniformity in line contact press region is easily maintained comparing with the surface press type. Using the roll type process, continues roll to roll production system to replicate micro structures to polymer sheet could be possible.

Fig. 1 UV nanoimprint process flow

Fig. 2 application field of nanoimprint process (required pattern size and imprint area)

Fig. 3 several type of nanoimprint tool, (a) flat surface press type, (b) step and repeat type, and (c) roller press type
3.1 Press type

Fig. 4 shows our developed flat surface press type nanoimprint tool which is available for both of UV and thermal nanoimprint, and capable of 300 degreeC of heating temperature and 50kN of press force. Also, step and repeat operation is possible in 100mm square region with sub-micron positioning accuracy. The system consists of motor controlled press mechanism, UV light source with 365nm of peak wavelength, XY stage and vacuum chamber to control process condition. Also a self adjusting mechanism to compensate tilt error between mold and substrate surface has been developed and installed in the system.

3.2 Roll to roll type

We have newly developed roll to roll type nanoimprint system for continuous micro pattern replication. Fig. 5 shows developed UV roll to roll nanoimprint system configuration. The system consists of UV resin coater to coat the resin with pre-determined film thickness to polymer sheets, press roll, mold roll, UV light source and sheet feed rollers to feed the film with constant tension. UV resin filled into mold pattern at line contact point of the press and the mold roller, and cure the resin by UV light. Patterned sheet is automatically remolded after UV curing by sheet tension.

4. Experimental results

Fig. 6 shows replication results of line and space pattern by UV nanoimprint process. The replication was performed by using commercial available standard quartz mold and UV resin of PAK-01 onto 4inch silicon substrate. A small feature size pattern less than 100nm was obtained to optimize the process parameters, initial UV resin thickness, press force, illumination power of UV light and release layer condition. Silicon substrate can be etched by applying the imprinted pattern as an etching mask. Fig. 7 shows dry etched structures of silicon substrate. Microstructure can be fabricated as same way as conventional dry etching process by using UV nanoimprinted pattern as a mask.
Fig. 8 and Fig. 9 show pattern replication uniformity in one shot imprint area (10mm square) and different shot position at step and repeat operation (five positions), respectively. Applying the self adjusting mechanism to compensate tilt error resulted in very good uniformity in one shot area and different position in a wafer.

Fig. 10 shows replication results of UV roll to roll nanoimprint process. A cell structure was replicated onto PET sheet (50um thickness) without defects to optimize the process conditions, that are UV resin coating thickness, replication speed, press force, sheet tension and treatment of mold release layer. A nanostructures with less than 100nm feature size were also replicated by the roll to roll process to polymer sheet.

5. Conclusions

UV nanoimprint process is very attractive microfabrication method. Many kinds of application could be promised using its process advantages such as low stress and no heat cycle process. In order to accelerate industrialization of nanoimprint process, large area and higher throughput nanoimprint process and tools must be developed. Roll type of process is one of reasonable solution to meet the demands for industrialization.

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References