NANO-MACHINING TECHNIQUE ON QUARTZ AND ITS APPLICATION TO NANOIMPRINT LITHOGRAPHY

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Abstract

Quartz has the potential to be developed as a device because of its material properties including piezoelectricity, isolation, transparency, high hardness, and high thermal stability[1]. The major obstacle to developing MEMS and NEMS techniques on quartz is the machining difficulty and the charging problem resulting from isolation in the e-beam exposure process.

The latest and greatly-respected application of quartz is molding in nanoimprint lithography technology (NIL). NIL differs from traditional lithography in the exposure and development process, which is replaced by a process in which a resist on substrate is imprinted by a patterned mold. It is a high-throughput technique that saves much processing time and cost.[2]

According to the course of polymerization, NIL is classified as thermal-cured NIL and photo-cured NIL. The process of performing thermal-cured NIL is shown in Fig.1. It includes (1) heating the resist to glass transition temperature, (2) pressing the mold to create a thickness contrast in polymer, (3) cooling down and removing the mold, (4) transferring the pattern down to polymer through RIE to remove the residual polymer, (5) metal deposition, (6) lift-off[2,3]. In the imprint process, heating up and cooling down takes a lot of time. Furthermore, volume shrinkage of the resist in the thermal cycle limits the resolution of the imprint[4]. To avoid volume shrinkage and shorten the process time, a low-viscosity and photo cross-linked polymer is used as the resist in photo-cured NIL. The process of photo-cured NIL is shown in Fig.2. It includes (1) dispensing the etch barrier, (2) pressing the mold and exposing with UV through the back side, (3) removing the mold and leaving low-aspect ratio features in the etch barrier, (4) breakthrough and transferring the etch[5]. Because the polymer is cross-linked by photo exposure and the glass transition temperature is lower, the process time for heating up and cooling down is greatly reduced. Moreover, the pressure in the press process is lower since the polymer is a low-viscosity liquid. In this research, quartz is selected as the mold material because of its transparency and high hardness.

After imprinting, three sides of the patterned polymer are in contact with the mold and one side is in contact with the substrate. If the surface energy of the mold is greater than that of the substrate, there is a high possibility that the patterned polymer will adhere to the mold and rip away from the substrate. It is therefore necessary to modify the surface energy of the mold with a self-assembling monolayer to ensure easy release of the polymer.[6]

This research utilizes the conducting polymer Espacer300 as a conducting layer to dissipate the charging effect. After E-beam lithography, the quartz mold is fabricated by metal evaporation, lift-off, and a reactive ion etch (Fig.3). Afterwards, the surface of the quartz mold is treated by dodecyltrichlorosilane in toluene.[7] Photo-solidification NIL is accomplished using the surface-treated mold and photo cross-linked polymer mr-L 6000.3Xpe[8].

This research has successfully defined 100nm-width resist features (Fig.4) and 200nm-width metal mask (Fig.5). Features of 500nm are resolved on the mode (Fig.6) and transferred to the polymer after imprinting (Fig.7).

REFERENCES

[1] J. S. Danel, and G. Delapierre,1991. Quartz: a material for micordevices, J. Micromech. Microeng 1,187-198.
[2] S. Y. Chou, P. R. Krauss, and P. J. Renstrom, 1996.Nanoimprint lithography. J. Vac. Sci. Technol/ B 14(6), 4129-4133.
[3] M. Li, J. Wang, L. Zhuang, and S. Y. Chou, 2000.Fabrication of circular optical structures with a 20nm minimum feature size using nanoimprint lithography. Appl. Phys. Lett., 76(6), 673-675.
[4] M. Komuro, J. Taniguchi, S. Inoue, N. Kimura, Y. Tokano, H. Hiroshima, and S. Matsui, 2000. Imprint Characteristic by Photo-Induced Solidification of Liquid Polymer, Jpn. J. Appl. Phys. 39,7075-7079.
[5] M. Colburn, S. Johnson, M. Stewart, S. Damle, T. Bailey, B. Choi, M. Wedlake, T. Michaelson, S.V. Sreenivasan, J. Ekerdt, C.G. Wilson, 1999. Step and Flash imprint lithography: A new approach to high-resolution patterning. Proc. of SPIE. 3676(1) ,379-389.
[6] T. Bailey, B. J. Choi, M. Colburn, M. Meissl, S. Shaya, J. G. Ekerdt, S. V. Sreenivasan, and C. G. Willson,

2000.Step and flash imprint lithography: Temple surface treatment and detect analysis, J. Vac. Sci. Technol. B18（6）,3572-3577.
[7] M. Tormen, T. Borzenko, G. Schmidt, J. Liu, and L.W. Molenkamp,2000. Thermocurable polymers as resists for imprint lithography. Electronics Letters 36(11), 983-984.
[8] K. Pfeiffer, F. Reuther, M. Fink, G. Gruetzner, P. Carlberg, I. Maximov, L. Montelius, J. Seekamp, S. Zankovych, C.M. Sotomayor-Torres, H. Schulz, and H.C. Scheer,2003. A comparison of thermally and photochemically cross-linked polymers for nanoimprinting, Microelectronic Engineering 67-68,266-273.

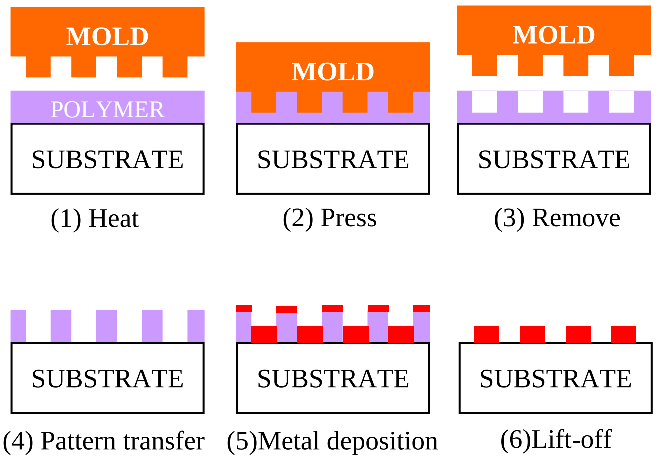

Fig. 1. Nanoimprint lithography process

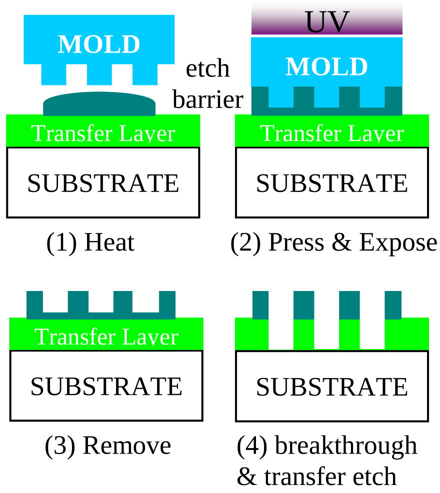

Fig. 2. Step and flash imprint lithography process

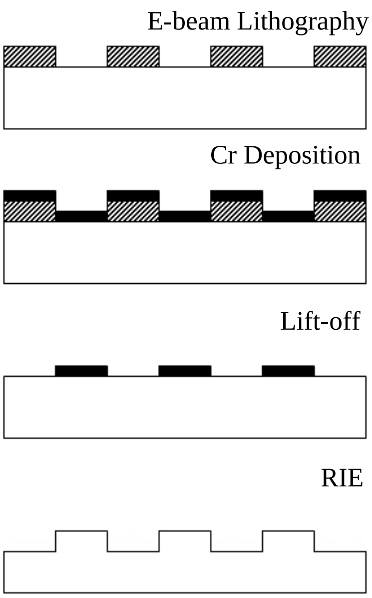

Fig. 3. Quartz mold fabrication process

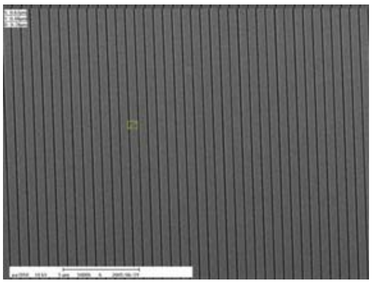

Fig. 4. Resist feature of 100nm width and 600nm period.

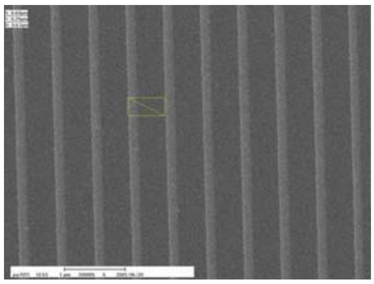

Fig. 5. Metal mask feature of 200nm width and 600nm period after lift-off.

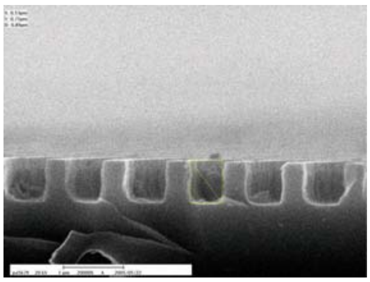

Fig. 6. Features of 500nm width and 1000nm period on quartz mold.

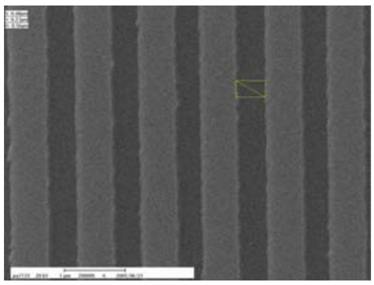

Fig. 7. Features of 500nm width and 1000nm period transferred to the polymer after imprinting.