Photocurable Nanoimprint Lithography (P-NIL): An Enabling Technology for MEMS and Nanophotonics

CNF Fellows Project

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Website: https://confluence.cornell.edu/display/CNFUserWiki/UV+Nanoimprint+Process+using+mr-XNIL26+resist

Primary CNF Tools Used: Nanoimprint NX-2500, MVD 100, Oxford 82 etcher, Unaxis 770 deep Si etcher, Oxford Cobra ICP etcher, SEM

Abstract:

We evaluate a new photocurable imprint resist (mr-XNIL26) from Microresist Technology and develop a working photocurable nanoimprint process on various substrates using the Nanonex NX-2500 imprint tool.

Summary of Research:

Nanoimprint lithography (NIL) is an emerging technology that has the advantage of high throughput with sub-10 nm resolution. The resolution is largely governed by the feature dimensions of the master or template, which can be defined by advanced photolithography or electron beam lithography. NIL has been a strategic method on the ITRS roadmap for the 45 nm node and below. In addition to electronics, NIL can be a benefit to many applications including nanophotonics, biotechnology, displays, and microelectromechanical systems.

The Nanonex NX-2500 has both thermal imprint (T-NIL) and photocurable imprint (P-NIL) capabilities. The photocurable imprint module uses 200W narrow band UV lamp. A quartz template was fabricated by sputter depositing a blanket layer of chrome in which a bright and dark field line space pattern was defined with the ASML DUV (248 nm) stepper producing a minimum feature size of 250 nm. The lithographically defined pattern was then transferred into the chrome using Cl_2/O_2/Ar mixed chemistry in the Trion inductively coupled plasma (ICP) tool. This etch produces smooth and perfectly anisotropic sidewall profiles, which are essential for optimum imprint replication. The chrome is used as a hard mask to etch the quartz substrate to a depth slightly less than the mr-XNIL26 resist thickness in the Oxford 80 reactive ion etching (RIE) tool using CF_4. The chrome is then removed by immersing the substrate in liquid chrome etchant. The template is coated with FOTS in the molecular vapor deposition (MVD) system to prevent the adherence of the resist in the imprint process. The Microresist Technology P-NIL resist system evaluated was mr-XNIL26, which is a new fluorine-modified UV nanoimprint resist with advanced release properties. We applied the mr-XNIL26-300 nm to a silicon wafer along with Omnicoat as an adhesion promoter, although the adhesion promoter is not necessary. The imprint is performed at room temperature and at a pressure of only 10 psi which is low compared to a thermal imprint process. The UV cure time is 30 seconds. The single layer P-NIL process is illustrated in Figure 1 adopted from Microresist Technology.

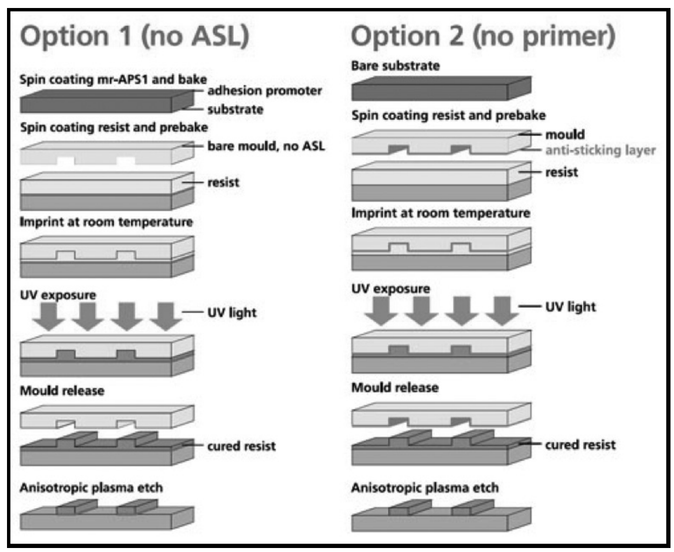

Figure 1: mr-XNIL26 P-NIL process overview from Microresist Technology.

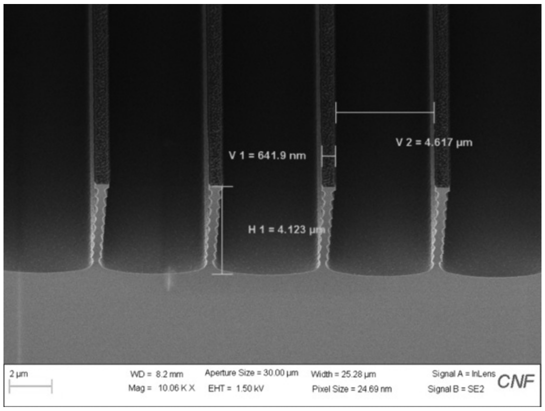

Figure 2: Bosch etch in Plasma-Therm SLR-770 of 600 nm features to an aspect ratio of 9:1.

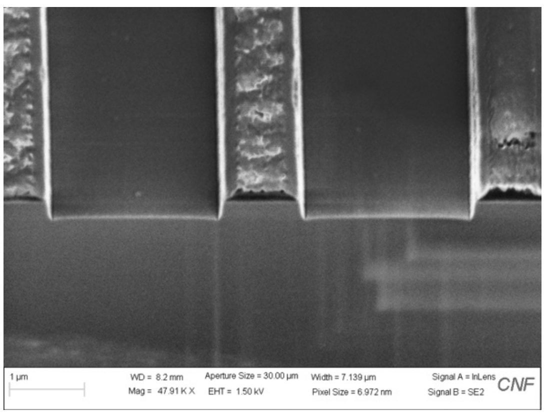

Figure 3: Oxford Cobra HBr silicon etch with a 4:1 selectivity of silicon to mr-XNIL26.

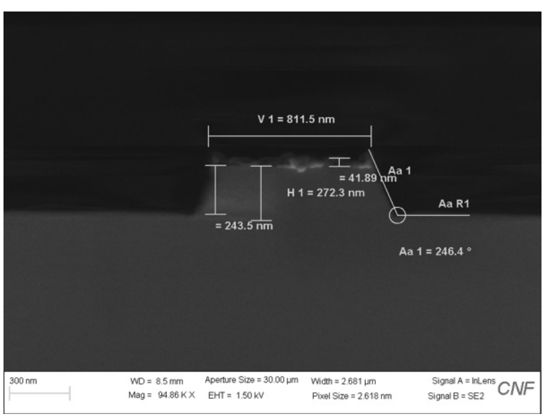

Figure 4: Silicon nitride etch using CH_2F_2/He in Oxford 100 ICP.

We used option 1 where Omnicoat® was used as an adhesion layer in place of mr-APS1. Residual layer etching is performed in the Oxford Plasmalab 80 using oxygen at low pressure (15 mTorr) and low power (50W) to retain critical dimensions and minimize the loss of resist. The post-imprint residual thickness layer is largely dependent on pattern density and feature size. The imprinted silicon wafers were etched with the Bosch deep silicon etch and the mixed SF_6/C_4F_8 etch in the Plasma-Therm SLR ICP. An additional wafer was etched with HBr in the Oxford Cobra ICP. The Bosch etch is commonly used in the fabrication of MEMS devices, while the mixed etch and the HBr etch are used for nanophotonics based devices. The P-NIL process using mr-XNIL26 resist was also applied to a silicon nitride layer.

Pattern transfer into Si_3N_4 was accomplished in the Oxford Plasmalab 100 ICP using CH_2F_2/He chemistry. This dielectric etch is used in the fabrication of oxide and nitride based nanophotonics devices here at CNF.

Figure 2 illustrates the results of the Bosch deep silicon etch for feature sizes of 600 nm etched to an aspect ratio of 9:1. The selectivity of silicon to the mr-XNIL26 resist is about 40:1, comparable to standard DUV and i-line photoresists. For the silicon etching with SF_6/C_4F_8 chemistry in the Plasma-Therm SLR-770, the selectivity of silicon to the mr-XNIL26 is 3:1, slightly less than standard DUV and i-line resists.

In Figure 3, we show the results of silicon etching in the Oxford Cobra ICP using HBr. Both the SF_6/C_4F_8 and the HBr etches produce highly anisotropic profiles with smooth sidewalls. Results of pattern transfer into silicon nitride using CH_2F_2/He in the Oxford 100 ICP are shown in Figure 4. The CH_2F_2/He chemistry is highly polymerizing and therefore highly selective with respect to imprint and conventional photoresists. The detailed process flow is posted on CNF user Wiki for reference.

In conclusion, we have evaluated a new photocurable imprint resist (mr-XNIL26) from Microresist Technology on our Nanonex NX-2500 imprint tool. This single layer resist system has been studied and the removal of residual resist has been optimized with proper plasma etch chemistry and parameters. We have then demonstrated effective pattern transfer into both silicon and silicon nitride using advanced ICP based reactive ion etching. We are currently working on combing e-beam lithography pattern and DUV pattern on one single template for imprint demonstration. We believe this process shows great potential in the fabrication of MEMS and photonics-based devices.