Pattern Replication of 100 nm to Millimeter-Scale Features by Thermal Nanoimprint Lithography

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Pattern replication of 100 nm to millimeter-scale features by thermal nanoimprint lithography

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Nanoimprint lithography (NIL) has demonstrated high resolution of 5 nm and molecular scale pattern replication [1-2]. On the other side, for very large features such as bonding or welding pads, more polymer must be displaced over longer distances than for small features, hence more challenging to accomplish by NIL. A popular approach to replicate patterns having very different sizes involves a mix-and-match method, a two-step process where small features are patterned by NIL while large features by photolithography. However, it is desirable to use one NIL step only, and pattern size ranging from 250 nm to 100 μm has been demonstrated previously by NIL [3]. Here we will study the potential of NIL for mm-scale features while retaining reasonable pattern duplication fidelity for nanoscale features.

The mould for NIL with pattern height 250 nm consists of square and line patterns with size up to 2 mm and a 200 nm period grating over the rest 4" wafer, and was fabricated by the mix-and-match method. To facilitate the subsequent metal liftoff process, the substrate for imprint consists of three layers: a 160 nm crossed-linked polymer ARC*, a 7 nm SiO_2, and a 250 nm PMMA resist with molecular weight 12k. After NIL, PMMA was etched for 130-200 nm by oxygen RIE, followed by SiO_2 RIE using CHF_3 gas that etched another 8 nm PMMA, and then the pattern was transferred into ARC with over etching to create an undercut profile. Next, 30 nm Cr was evaporated and lifted off by dissolving ARC, and the pattern was etched into silicon.

The as-imprinted PMMA profile for typical large features and cross-section for 200 nm period grating is shown in Fig. 1. For mm-size features the polymer surface is curved, indicating the mould and substrate were deformed during NIL. After RIE PMMA, here 180 nm, the grating lines shrank (Fig. 2(a)) into a triangular shape due to lateral etch; however, the line-width of the final pattern is determined by the base-width of the triangular profile, which is 20 nm less than the mould line-width. Such a tapered profile would make metal liftoff impossible, yet this proved not a problem for the tri-layer resist structure (Fig. 2(b)).

The final duplicated pattern is shown in Fig. 3. From these images we can see that, for nanoscale features the line is about 20 nm wider than that in the mould (in practice, this dimension change could be compensated by modifying the original mould feature size accordingly), for square patterns the maximum replicable feature size is 1.3 mm, and for line patterns it is 0.7 mm, about half that of square pattern, since now polymer can only be displaced at two directions. Larger features could be replicated by etching even more PMMA after NIL, but at the cost of greater dimension change for nanoscale pattern.

It should be noted that we have only used moderate imprint conditions: 200°C and 20 bar for 20 minutes with 250 nm resist. We attribute the successful duplication of mm-scale features mainly to the low molecular weight thus low viscosity of PMMA, and the over-etching of PMMA after NIL. Finally, we believer a more rigid mould and substrate could further improve the process by reducing deformation.

* ARC: anti-reflection coating, Brewer Science XHRiC-16.

[1]. MD Austin, H Ge, W Wu, M Li, Z Yu, D Wasserman, SA Lyon, and SY Chou, Appl. Phys. Lett., 84(26), 5299 (2004).
[2]. F Hua, Y Sun, A Gaur, MA Meitl, L Bilhaut, L Rotkina, J Wang, P Geil, M Shim and JA Rogers, Nano Lett., 4(12), 2467 (2004).
[3]. C Perret, C Gourgon, F Lazzarino, J Tallal, S Landis and R Pelzer, Microelectron. Eng., 73-74, 172 (2004).

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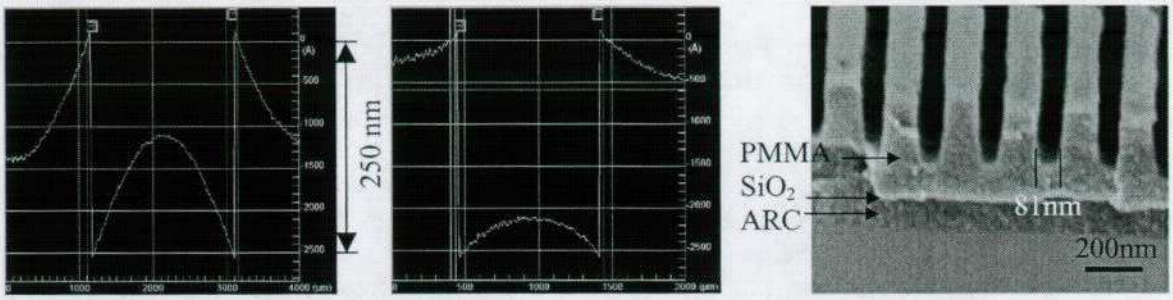

Figure 1 As-imprinted PMMA surface profile for 2 mm square (left) and 1 mm square (center), and cross-section of 200 nm period grating with average trench-width 81 nm (equal to the mould line-width) (right). The NIL was performed at 200°C and 20 bar for 20 min using 250 nm12k molecular weight PMMA.

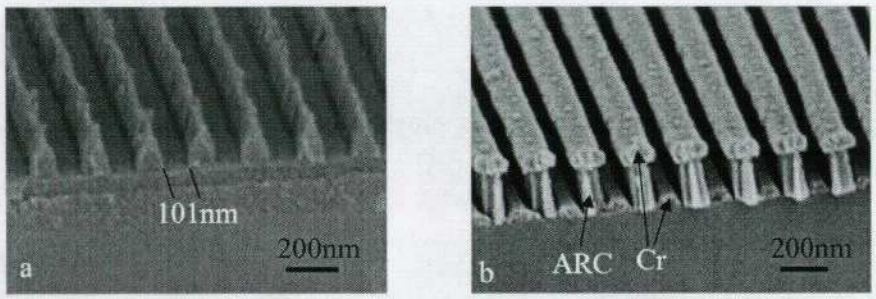

Figure 2 (a) PMMA cross-section after 180 nm oxygen RIE that widened the trench for about 20 nm; (b) after RIE ARC and then evaporate 30 nm Cr, noting that the undercut profile makes the subsequent liftoff straightforward.

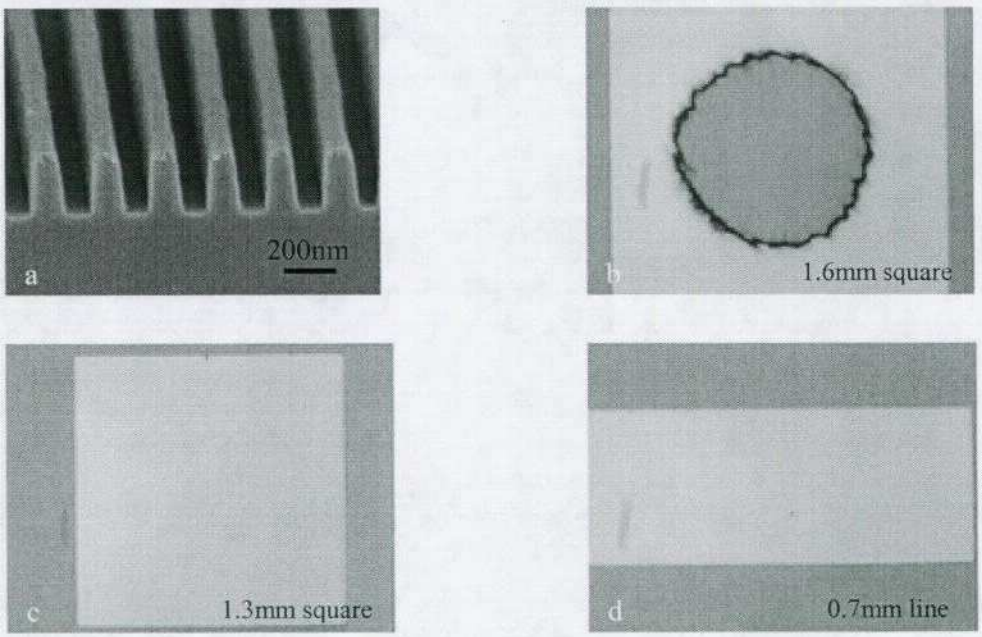

Figure 3 Completed pattern duplication into Si with pattern height 225 nm. (a) 200 nm period grating with resulted line-width 98 nm, 17 nm wider than original mould line-width; (b) 1.6 mm square, not fully duplicated, similar for larger squares; (c) 1.3 mm square, fully duplicated, similar for smaller squares; and (d) section of a 0.7 mm-wide line, wider lines were not fully duplicated. (Cr etching mask not removed here)