

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization  
International Bureau



(43) International Publication Date  
29 April 2010 (29.04.2010)

(10) International Publication Number  
**WO 2010/047769 A1**

PCT

(51) International Patent Classification:  
**G03F 7/00** (2006.01)

(21) International Application Number:  
PCT/US2009/005692

(22) International Filing Date:  
20 October 2009 (20.10.2009)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:  
61/107,238 21 October 2008 (21.10.2008) US  
12/581,236 19 October 2009 (19.10.2009) US

(71) Applicant (for all designated States except US):  
**MOLECULAR IMPRINTS, INC.** [US/US]; 1807 West  
Braker Ln, Bldg. C-100, Austin, Texas 78758-3605 (US).

(72) Inventors: **XU, Frank. Y.**; 3814 Harvey Penick Dr.,  
Round Rock, Texas 78664 (US). **SREENIVASAN, Sidl-  
gata, V.**; 10502 Grand Oak Drive, Austin, Texas 78750  
(US).

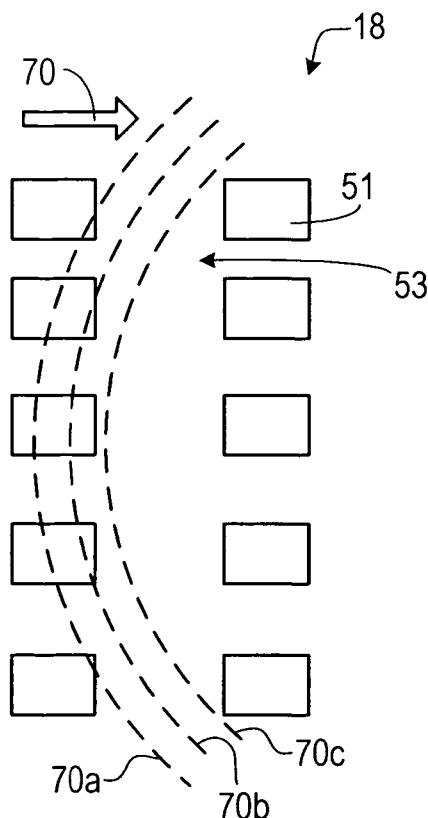
(74) Agent: **WOOD, Laura**; PO Box 81536, Austin, Texas  
78708-1536 (US).

(81) Designated States (unless otherwise indicated, for every  
kind of national protection available): AE, AG, AL, AM,  
AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ,  
CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO,  
DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT,  
HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP,  
KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD,  
ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI,  
NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD,  
SE, SG, SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT,  
TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

[Continued on next page]

(54) Title: REDUCTION OF STRESS DURING TEMPLATE SEPARATION

(57) Abstract: Separation of an imprint lithography template and a patterned layer in an imprint lithography process may result in stress to features of the template and/or features of the patterned layer. Such stress may be reduced by minimizing open areas on the template, including dummy features within the open areas, and/or selective positioning of features on the template.



**FIG. 4A**

WO 2010/047769 A1



(84) **Designated States** (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, SM,

TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

**Published:**

— with international search report (Art. 21(3))

## REDUCTION OF STRESS DURING TEMPLATE SEPARATION FROM SUBSTRATE

## 5 CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit under 35 U.S.C. § 119(e)(1) of U.S. Provisional Patent Application No. 61/107,238 filed October 21, 2008, and U.S. Patent Application No. 12/581,236 filed October 19, 2009, both of which are hereby incorporated by reference herein in their entirety.

## 10 BACKGROUND INFORMATION

[0002] Nano-fabrication includes the fabrication of very small structures that have features on the order of 100 nanometers or smaller. One application in which nano-fabrication has had a sizeable impact is in the processing of integrated circuits. The semiconductor processing industry continues to strive for  
15 larger production yields while increasing the circuits per unit area formed on a substrate, therefore nano-fabrication becomes increasingly important. Nano-fabrication provides greater process control while allowing continued reduction of the minimum feature dimensions of the structures formed. Other areas of development in which nano-fabrication has been employed include  
20 biotechnology, optical technology, mechanical systems, and the like.

[0003] An exemplary nano-fabrication technique in use today is commonly referred to as imprint lithography. Exemplary imprint lithography processes are described in detail in numerous publications, such as U.S. Patent Publication No.

2004/0065976, U.S. Patent Publication No. 2004/0065252, and U.S. Patent No. 6,936,194, all of which are hereby incorporated by reference.

[0004] An imprint lithography technique disclosed in each of the  
aforementioned U.S. patent publications and patent includes formation of a relief  
5 pattern in a polymerizable layer and transferring a pattern corresponding to the  
relief pattern into an underlying substrate. The substrate may be coupled to a  
motion stage to obtain a desired positioning to facilitate the patterning process.  
The patterning process uses a template spaced apart from the substrate and a  
formable liquid applied between the template and the substrate. The formable  
10 liquid is solidified to form a rigid layer that has a pattern conforming to a shape of  
the surface of the template that contacts the formable liquid. After solidification,  
the template is separated from the rigid layer such that the template and the  
substrate are spaced apart. The substrate and the solidified layer are then  
subjected to additional processes to transfer a relief image into the substrate that  
15 corresponds to the pattern in the solidified layer.

## BRIEF DESCRIPTION OF DRAWINGS

[0005] So that the present invention may be understood in more detail, a  
description of embodiments of the invention is provided with reference to the  
20 embodiments illustrated in the appended drawings. It is to be noted, however,  
that the appended drawings illustrate only typical embodiments of the invention,  
and are therefore not to be considered limiting of the scope.

[0006] FIG. 1 illustrates a simplified side view of one embodiment of a lithographic system in accordance with the present invention.

[0007] FIG. 2 illustrates a simplified side view of the substrate shown in FIG. 1 having a patterned layer positioned thereon.

5 [0008] FIG. 3 illustrates a simplified side view of a template and patterned layer during separation.

[0009] FIG. 4A illustrates a simplified top down view of a template having an ideal separation front.

10 [0010] FIG. 4B illustrates a simplified top down view of a template with a separation front with portions of the separation front having different rates of propagation.

[0011] FIGS. 5A and 5B illustrate a simplified top down view of a template having clusters with dense feature areas, each cluster being separated by a large open area and each dense feature area within each cluster being separated by a smaller open area.

[0012] FIGS. 6A-6G illustrate sequential movement of a separation front with portions of the separation front having different rates of propagation.

[0013] FIG. 7 illustrates a simplified top down view of a substrate having damage within dense feature areas.

20 [0014] FIG. 8 illustrates a simplified side view of an exemplary embodiment of a template.

[0015] FIG. 9 illustrates a top down view of the template shown in FIG. 8.

[0016] FIG. 10 illustrates a simplified side view of an exemplary embodiment of a template.

[0017] FIG. 11 illustrates a top down view of an exemplary template having a continuous block of dense features parallel to separation front.

5 [0018] FIG. 12 illustrates a top down view of an exemplary embodiment of a template having a continuous block of dense features parallel and at an angle to separation front.

[0019] FIG. 13 illustrates a top down view of an exemplary embodiment of a template having multiple continuous blocks of dense features parallel and  
10 perpendicular to separation front.

[0020] FIG. 14 illustrates a top down view of an exemplary embodiment of a template having multiple continuous blocks of dense features parallel and perpendicular to separation front.

15 DETAILED DESCRIPTION

[0021] Referring to the figures, and particularly to FIG. 1, illustrated therein is a lithographic system 10 used to form a relief pattern on substrate 12. Substrate 12 may be coupled to substrate chuck 14. As illustrated, substrate chuck 14 is a vacuum chuck. Substrate chuck 14, however, may be any chuck  
20 including, but not limited to, vacuum, pin-type, groove-type, electromagnetic, and/or the like. Exemplary chucks are described in U.S. Patent No. 6,873,087, which is hereby incorporated by reference.

[0022] Substrate 12 and substrate chuck 14 may be further supported by stage 16. Stage 16 may provide motion about the x-, y-, and z-axes. Stage 16, substrate 12, and substrate chuck 14 may also be positioned on a base (not shown).

5 [0023] Spaced-apart from substrate 12 is a template 18. Template 18 generally includes a mesa 20 extending therefrom towards substrate 12, mesa 20 having a patterning surface 22 thereon. Further, mesa 20 may be referred to as mold 20. Template 18 and/or mold 20 may be formed from such materials including, but not limited to, fused-silica, quartz, silicon, organic polymers, 10 siloxane polymers, borosilicate glass, fluorocarbon polymers, metal, hardened sapphire, and/or the like. As illustrated, patterning surface 22 comprises features defined by a plurality of spaced-apart recesses 24 and/or protrusions 26, though embodiments of the present invention are not limited to such configurations. Patterning surface 22 may define any original pattern that forms the basis of a 15 pattern to be formed on substrate 12.

[0024] Template 18 may be coupled to chuck 28. Chuck 28 may be configured as, but not limited to, vacuum, pin-type, groove-type, electromagnetic, and/or other similar chuck types. Exemplary chucks are further described in U.S. Patent No. 6,873,087, which is hereby incorporated by reference. Further, chuck 20 28 may be coupled to imprint head 30 such that chuck 28 and/or imprint head 30 may be configured to facilitate movement of template 18.

[0025] System 10 may further comprise a fluid dispense system 32. Fluid dispense system 32 may be used to deposit polymerizable material 34 on

substrate 12. Polymerizable material 34 may be positioned upon substrate 12 using techniques such as drop dispense, spin-coating, dip coating, chemical vapor deposition (CVD), physical vapor deposition (PVD), thin film deposition, thick film deposition, and/or the like. Polymerizable material 34 may be disposed  
5 upon substrate 12 before and/or after a desired volume is defined between mold 20 and substrate 12 depending on design considerations. Polymerizable material 34 may comprise a monomer as described in U.S. Patent No. 7,157,036 and U.S. Patent Publication No. 2005/0187339, all of which are hereby incorporated by reference.

10 [0026] Referring to FIGS. 1 and 2, system 10 may further comprise an energy source 38 coupled to direct energy 40 along path 42. Imprint head 30 and stage 16 may be configured to position template 18 and substrate 12 in superimposition with path 42. System 10 may be regulated by a processor 54 in communication with stage 16, imprint head 30, fluid dispense system 32, and/or  
15 source 38, and may operate on a computer readable program stored in memory 56.

[0027] Either imprint head 30, stage 16, or both vary a distance between mold 20 and substrate 12 to define a desired volume therebetween that is filled by polymerizable material 34. For example, imprint head 30 may apply a force to  
20 template 18 such that mold 20 contacts polymerizable material 34. After the desired volume is filled with polymerizable material 34, source 38 produces energy 40, e.g., broadband ultraviolet radiation, causing polymerizable material 34 to solidify and/or cross-link conforming to shape of a surface 44 of substrate



12 and patterning surface 22, defining a patterned layer 46 on substrate 12. Patterned layer 46 may comprise a residual layer 48 and a plurality of features shown as protrusions 50 and recessions 52, with protrusions 50 having thickness  $t_1$  and residual layer having a thickness  $t_2$ .

5 [0028] The above-mentioned system and process may be further employed in imprint lithography processes and systems referred to in U.S. Patent No. 6,932,934, U.S. Patent Publication No. 2004/0124566, U.S. Patent Publication No. 2004/0188381, and U.S. Patent Publication No. 2004/0211754, each of which is hereby incorporated by reference.

10 [0029] Referring to FIG. 3, template 18 may contain dense areas 51 (i.e., dense areas of features 24 and/or 26 of template 18) in combination with open areas 53 (e.g., streets of template 18) that may present unique challenges during separation of patterned layer 46 and template 18. For example, if the aspect ratio of features 24 and 26 (ratio of feature height to width) is equal to and/or  
15 greater than approximately 1:1, the friction force between template 18 and patterned layer 46 may increase as well as the adhesion force providing torsional and/or shear stress on features 24 and 26 and/or features 50 and 52.

[0030] As the separation of template 18 from patterned layer 46 generally involves adhesion and friction forces, separation front 70 may move similar to  
20 propagation of a crack. Separation energy between template 18 and patterned layer 46 may be considered similar to fracture separation energy and have different magnitudes depending on the density of features 24 and 26 and/or features 50 and 52. For example, in FIG. 3, separation energy of dense areas 51

may have a magnitude  $G_D$  while separation energy of open areas 53 may have a magnitude of  $G_O$ . As template 18 includes substantial dense areas 51 as compared to open area 53, there may be a large difference in separation energy ( $\Delta G = G_D - G_O$ ) as template 18 passes through dense areas 51 and open areas 53.

[0031] As the separation of template 18 from patterned layer 46 may move similar to crack propagation, the separation front 70 may be discontinuous at certain periods of time. Additionally, the separation front 70 may be able to jump several hundred microns at a time. Further, the separation front 70 of template 18 and patterned layer 46 may move at a relatively steady pace within dense area 51; however, as the template 18 and patterned layer 46 separate within the open area 53, the propagation speed of the separation front 70 may substantially increase and/or propagation speed of the separation front 70 may substantially decrease in dense areas 51. The contrasting propagation rate of the separation front 70 within the dense area 51 and the open area 53 may introduce torsional and/or shear stress on features 24 and 26 and/or features 50 and 52.

[0032] FIGS. 4-7 illustrate exemplary torsional and/or shear stress that may occur on features 24 and 26 of template 18 and/or features 50 and 52. In particular, FIG. 4A illustrates an ideal separation front 70. As illustrated, an ideal separation front 70 may move at a relatively steady pace in dense feature areas 51 and in open areas 53. For example, separation front 70a and 70b propagating through dense areas 51 and open areas 53 may move at a relatively steady pace. Additionally, separation front 70c propagating through open areas

53 also moves at a relatively steady pace. However, as shown in FIG. 4B, separation front 70d rarely, if ever, follows an ideal and may lag in dense areas 51 and/or increase its pace in open areas 53.

[0033] Referring to FIGS. 5A and 5B, template 18 may include dense feature areas 51 and open areas 53. For example, template 18 may be provided with an array of clusters 55 having dense feature areas 51 as shown in FIG. 5A. An exemplary dense feature area 61 may contain, for example, grating structures having 32 nm wide line situated at about 32 nm apart (1:1), and may have a line depth of 70 nm. Each cluster 55 may be separated by open area 53a. For example, open area 53a may have a length  $L_1$  (e.g., an exemplary length  $L_1$  is approximately 1 mm). Further, each cluster may be formed of multiple dense feature areas 51 separated by open areas 53b (e.g., an exemplary length  $L_2$  is approximately 75 microns). For example, as illustrated in FIG. 5B, dense feature areas 51a-51d may be separated by open areas 53b (e.g., streets). Open areas 53b may have a length  $L_2$  (e.g., approximately 75 microns).

[0034] FIGS. 6A through 6G illustrate propagation of separation front 70 during separation of template 18 from substrate 12 as described in relation to FIGS. 1 and 2. As shown in FIGS. 6A through 6E, propagation of separation front 70 may be at a substantially steady pace at the initiation of separation; however, as separation front 70 moves through both dense areas 51 and open areas 53a and 53b, pace of separation front 70 may decrease in dense areas 51 and/or increase in open areas 53a and 53b and may result in lag areas 57 wherein separation front may not be ideal as shown in FIG. 6G.

[0035] Lag areas 57 may cause torsional and/or shear stress on features 24 and/or 26 and/or features 50 and 52 formed on substrate as described in relation to FIGS. 1 and 2. Such torsional and/or shear stress may be heightened in areas adjacent to open areas 53a and compared to open areas 53b shown in FIG. 7. For example, Applicants have identified at magnifications greater than 20x regions adjacent to open areas 53a on template 18 (e.g., open areas 53a having lengths at about 1 mm) and/or corresponding regions of substrate 12 are subjected to increased torsional and/or shear stress that may result in tearing; however, regions adjacent to open areas 53b (e.g., open areas 53b having lengths significantly less than 1 mm) are substantially free of tearing.

[0036] Torsional and/or shear stress on features 24 and 26 and/or features 50 and 52 during patterning as described in relation to FIGS. 1 and 2 may be reduced by minimizing open areas (e.g., streets) of template 18 and/or providing dummy features in open areas of template 18 as described herein. For example, torsional and/or shear stress may be reduced when using these techniques while imprinting with dense templates 18 wherein magnitude of protrusions 26 is equal to or less than approximately 100 nm in lateral dimension, magnitude of lateral dimension of recessions 24 provides an approximate 1:2 feature size to space ratio or denser feature area (such as 1:1), and/or aspect ratio (i.e., feature height divided by feature width) is between approximately 0.5 to 3.

[0037] FIG. 8 illustrates an exemplary embodiment of template 18 having a reduced length open area 53a between clusters 55a<sub>1</sub> and 55a<sub>2</sub>, and more

specifically, open area 53a of template 18 may be less than approximately 200 microns. It should be noted that although Figures illustrate clusters 55 in relative periodic intervals, clusters 55, feature areas 51, and/or open areas 53 may be non-periodic groupings. For example, features 24 and 26 within clusters 55 may occur at non-regular intervals (e.g., sporadic).

[0038] In one embodiment, open area 53 of template 18 may be less than approximately 100 microns. Limiting open area 53a of template 18 to less than approximately 200 microns, and even further to less than approximately 100 microns, may substantially reduce the amount of torsional and/or shear stress introduced on features 24 and 26 and/or features 50 and 52. For example, as separation front 70 propagates to the open area 53a, separation rate of template 18 and patterned layer 46 may increase substantially; however, as open area 53a may be less than approximately 200 microns, such an increase rate of separation over the short distance of open area 53a may not be enough to introduce additional torsional and/or shear stress on features 24 and 26. Additionally, as the separation front 70 may be able to jump several hundred microns at a time, the separation front 70 may effectively temporarily bypass open area 53a and maintain the rate of separation between dense areas 51a<sub>1</sub> and 51a<sub>2</sub>.

[0039] In some circumstances, separation front 70 also may not have a uniform rate of propagation during separation of template 18 and patterned layer 46. For example, FIG. 9 illustrates a top down view of template 18 wherein separation front 70 includes different rates of propagation  $P_1$  and  $P_2$ . For

example, different rate of propagation may result from separation front 70 moving concurrently through dense areas 51a<sub>1</sub> and open area 53a. The rate of propagation for P<sub>2</sub> may substantially increase causing torsional and/or shear stress if separation front 70 increases its pace moving through open area 53a.

- 5 By limiting open areas 53a of template 18 to less than approximately 200 microns, and even further, to less than approximately 100 microns, separation front 70 may encounter dense areas 51 at a frequent rate and/or reduced open areas 53a that may effectively reduce the rate of propagation. For example, the separation front 70 propagating at rate P<sub>2</sub> may encounter a dense area 51a<sub>2</sub>
- 10 sooner magnitude of open area 53a is reduced, effectively reducing rate P<sub>2</sub>, and thus reducing the likelihood of substantial torsional and/or shear stress.

[0040] FIG. 10 illustrates another exemplary embodiment of template 18 having dummy features 60. Dummy features 60 may be used in lieu of or in combination with reduced magnitude open areas 53a described herein.

- 15 [0041] Dummy features 60 generally are low resolution, low cost filler features similar to features 24 and 26. Dummy feature 60 may be 100 nm to tens of micron in size. One or more dummy features 60 may be placed at periodic intervals within open areas 53a to define a dummy area 61. For example, dummy features 60 may be placed apart at 100 nm or larger distances
- 20 defining dummy area 61 as illustrated in FIG. 10. Generally, dummy area 61 may have separation energy of a magnitude G<sub>γ</sub> that is greater than the magnitude G<sub>0</sub> of open area 53a without dummy features 60. As such, the rate of propagation of separation front 70 may be less within the dummy area 61

compared to rate of propagation of the separation front 70 through the open area 53a without dummy features 60. This may reduce the distortional stress of features 24 and 26 during separation of template 18 and patterned layer 46.

[0042] From a separation force  $F_S$  perspective, assuming that separation

5 front 70 includes a radius  $R$ , then in general it may be preferred that at  $\frac{\partial F}{\partial R}$ ,

minimal fluctuations occur. Without dummy features, however,  $\frac{\partial F}{\partial R}$  may change

abruptly as separation front 70 moves from dense area 51 to open areas 53a (e.g., from dense area 51a<sub>1</sub> to open area 53a). The separation force  $F_S$  per area

of regions of dummy features 60 may be between the separation force  $F_S$  per

10 area of dense areas 51 and open areas 53a. As such, fluctuations in  $\frac{\partial F}{\partial R}$  may

be reduced by inserting dummy features 60 in open areas 53a.

[0043] Referring to FIGS. 11-14, positioning of features 24 and/or 26 of

template 18 within dense areas 51 may reduce torsional stress and/or shear stress. Positioning of features 24 and/or 26 within dense areas 51 may be used

15 in lieu of or in combination with dummy features 60/dummy areas 61 and/or minimized magnitude of open areas 53a as described herein.

[0044] FIG. 11 illustrates a top down view of an exemplary template 18

having features 24 and 26. Protrusions 26 may be defined by grating length  $H_L$  and grating width  $H_P$ . Generally, grating length  $H_L$  may be associated with the

20 longest dimension of protrusion 26. As described in further detail by Landis, et al., having separation front 70 parallel to grating length  $H_L$  dimension may increase fracture energy as compared to having separation front 70 parallel to

grating width  $H_P$  dimension (or separation front 70 perpendicular to grating length direction). See S Landis, et al. *Quantitative characterizations of a nanopatterned bonded wafer: force determination for nanoimprint lithography stamp removal*, Nanotechnology, 2008, at 125305, which is hereby incorporated  
5 by reference.

[0045] FIG. 12 illustrates an exemplary embodiment of template 18 having features 24 and 26 positioned at an angle  $\theta$  relative separation front 70. Angled features 24 and 26 may reduce separation energy. Features 24 and 26 may be less than approximately 100 nm wide with space and feature width of  
10 approximately 1:1 and aspect ratio of approximately 2:1. Features 24 and 26 may have a length greater than approximately 1 micron. Additionally, features 24 and 26 may form a continuous block 74.

[0046] FIG. 13 illustrates an exemplary embodiment of template 18 having grating length  $H_L$  dimension of protrusion 26 alternating in parallel and  
15 perpendicular positions in relation to separation front 70. For example, features 24 and 26 may form a continuous block 76 with grating length  $H_L$  dimension of protrusions 26 positioned parallel to separation front 70 and a continuous block 78 of features 24 and 26 with grating length  $H_L$  dimension of protrusions 26 positioned perpendicular to separation front 70. As illustrated in FIG. 13,  
20 continuous block 76a may include grating length  $H_{L1}$  dimension of protrusions 26 positioned parallel to separation front 70 and continuous block 76b may include grating length  $H_{L3}$  dimension of protrusions 26 positioned parallel to separation front 70. Similarly, continuous block 78a may include grating length  $H_{L2}$



dimension of protrusions 26 positioned perpendicular to separation front 70 and continuous block 78b may include grating length  $H_{L4}$  dimension of protrusions 26 positioned perpendicular to separation front 70. Grating length  $H_{L1}$ ,  $H_{L2}$ ,  $H_{L3}$ , and/or  $H_{L4}$  may have similar or different magnitudes depending on design considerations. Additionally, grating lengths  $H_L$  within each block 76 or 78 may be similar or different magnitudes depending on design considerations.

[0047] Blocks 76 and 78 need not alternate successively (e.g., parallel, perpendicular, parallel, perpendicular). Alternating blocks 76 and 78 may be designed such that separation energy may be reduced while maintaining pattern density of template 18. Any number of features 24 and 26 may be present within blocks 76 and/or 78. Features 24 and 26 may be less than approximately 100 nm wide with space and feature width of 1:1 and aspect ratio of 2:1. Features 24 and 26 may have a length greater than approximately 1 micron.

[0048] FIG. 14 illustrates an exemplary embodiment of template 18 having features 24 and 26 alternating between parallel and perpendicular positions in relation to separation front 70 in a radial shape. For example, features 24 and 26 may form a continuous block 82 of features 24 and 26 with grating length  $H_L$  dimension positioned parallel to separation front 70 and a continuous block 84 of features 24 and 26 with grating length  $H_L$  dimension positioned perpendicular to separation front 70. Additionally, parallel and/or perpendicular features 24 and 26 may be in a radial pattern. Radial pattern provides that the magnitude of the grating width  $H_P$  may vary along feature 26. For example, as shown in continuous block 84a, grating width  $H_{P6}$  dimension may increase along grating

length  $H_{L6}$  as protrusion 26 extends towards separation front 70. Providing features 24 and 26 in a radial pattern with alternating parallel and perpendicular positions may reduce separation energy while maintaining pattern density. Additionally, features 24 and 26 may exhibit a concave shape to reduce separation energy. For example, continuous block 82a may include features 24 and 26 having ends extending away from separation front 70 and center of features 24 and 26 extending toward separation front 70.

## WHAT IS CLAIMED IS:

1. An imprint lithography template, comprising:  
a plurality of clusters, each cluster having at least one dense feature area,  
5 the dense features area having a plurality of features with an aspect ratio  
between about 0.5 to 3, each cluster separated by an open area having a length,  
wherein magnitude of the length is equal to or less than about 200 microns.
2. The template of claim 1, wherein magnitude of the length is equal to or  
10 less than about 100 microns.
3. The template of any of the above claims, wherein magnitude of the length  
is adapted to reduce rate of propagation of a separation front.
- 15 4. The template of any of the above claims, wherein the open area includes  
at least one group of dummy features.
5. The template of claim 4, wherein the dummy features are positioned at a  
periodic interval within the open area, wherein the periodic interval is adapted to  
20 reduce propagation rate of a separation front.
6. The template of any of the above claims, wherein each dense feature area  
includes a plurality of protrusions and a plurality of recessions.

7. The template of claim 6, wherein the protrusions are equal to or less than approximately 100 nm.

8. The template of any of claims 6-7, wherein the protrusions are positioned  
5 on the template at an angle relative to a separation front.

9. The template of any of claim 8, wherein the position of the angle is adapted to reduce fracture energy during separation of the template from a patterned layer.

10

10. The template of any of claims 6-9, wherein at least a portion of the protrusions are positioned at an angle less than 90 degrees relative to a separation front, and at least a portion of the protrusions are positioned substantially perpendicular to the separation front.

15

11. The template of claim 10, wherein the angled protrusions are in a radial pattern.

12. The template of any of claims 10-11, wherein the perpendicular  
20 protrusions are in a radial pattern.

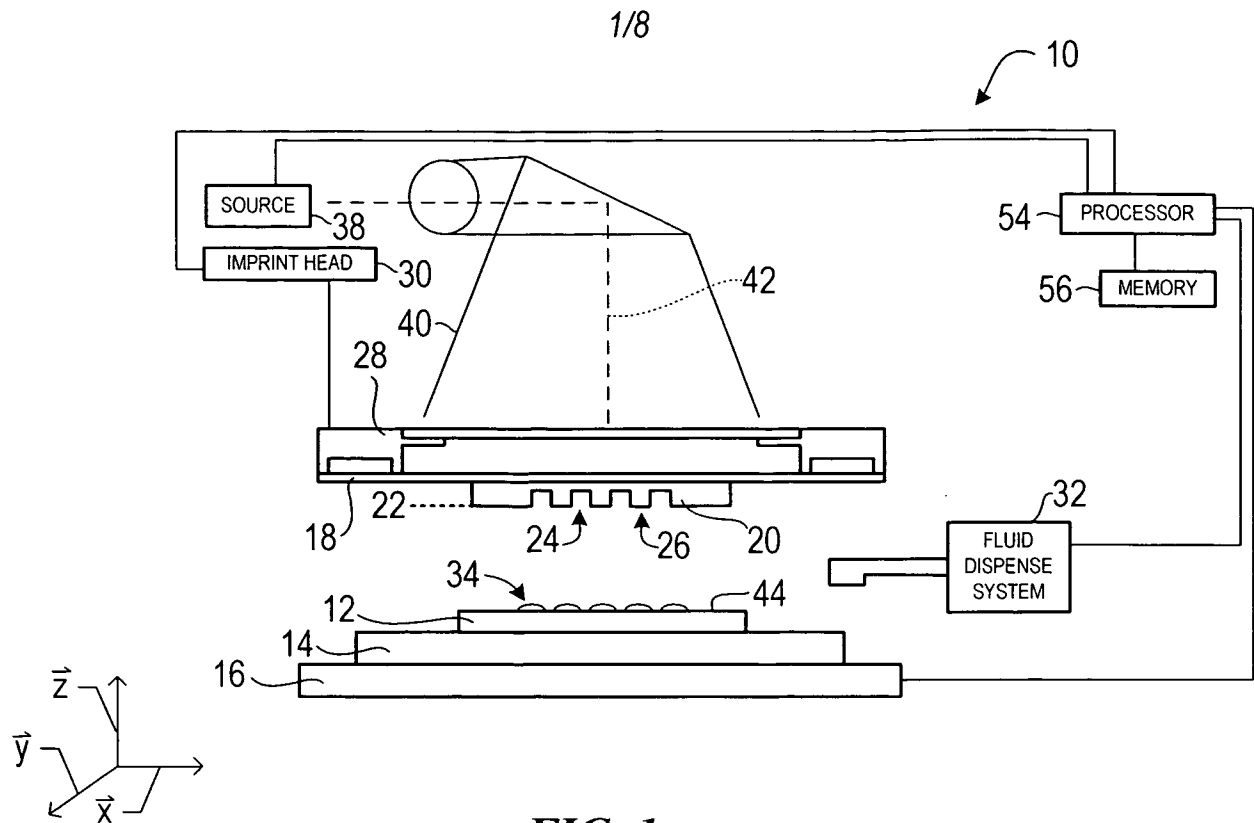
13. The template of any of claims 10-12, wherein features within the dense feature area have a concave shape such that a center of each feature bows towards the separation front.

5 14. The template of any of the above claims, wherein a first dense feature area includes features positioned substantially parallel to a separation front and a second dense feature area includes features positioned substantially perpendicular to the separation front.

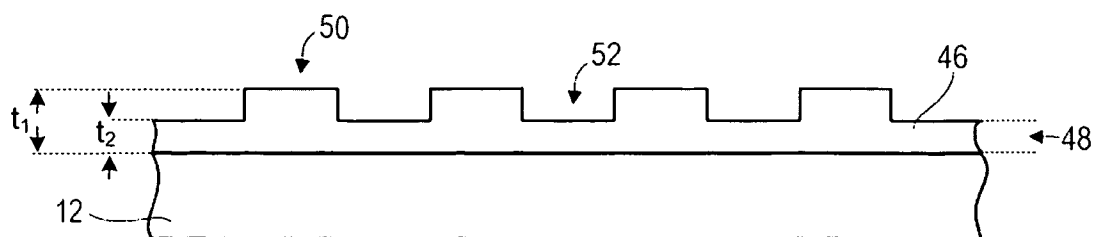
10 15. The template of any of the above claims, wherein the dense feature area includes at least one feature having a variable grating width, wherein the grating width increases towards a separation front.

15 16. The template of any of the above claims, wherein the dense feature area includes at least one feature having a variable grating length, wherein the grating length increases towards a center of each feature.

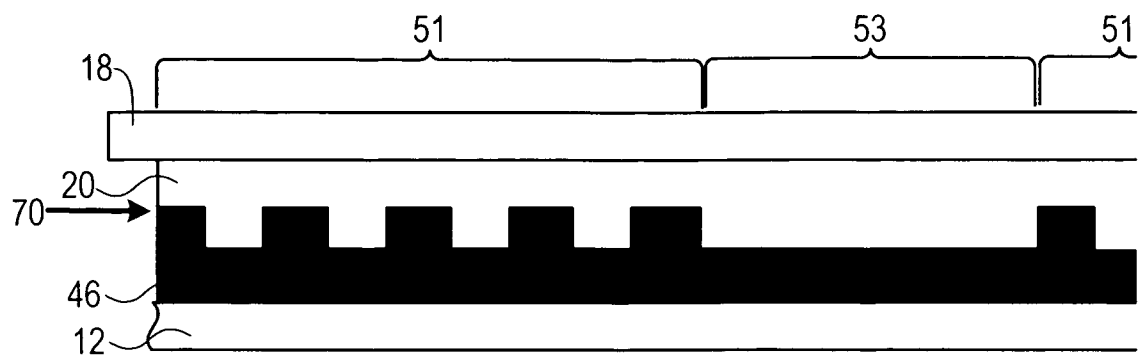
17. A method of using the template of claim 1, comprising:  
patterning polymerizable material positioned on a substrate, the  
20 polymerizable material patterned using the; and,  
separating the template from the patterned layer, wherein positioning of the dense feature areas and the open area on the template reduces propagation of a separation front.



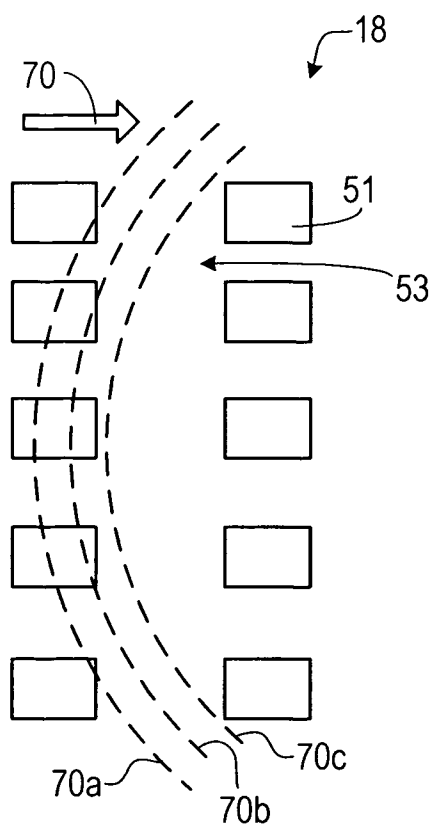
**FIG. 1**



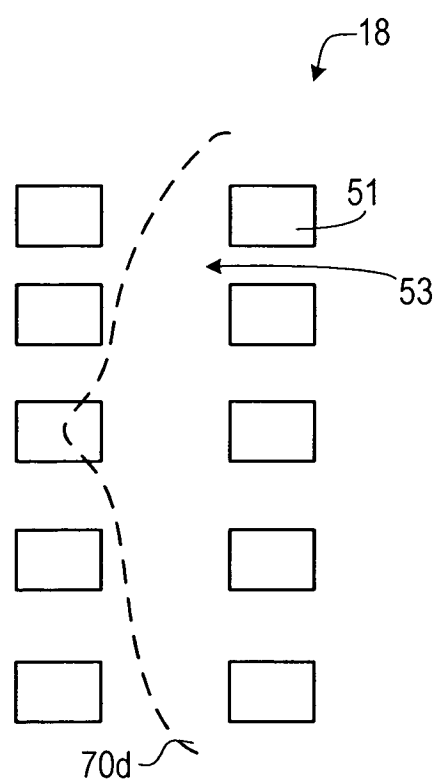
**FIG. 2**



**FIG. 3**

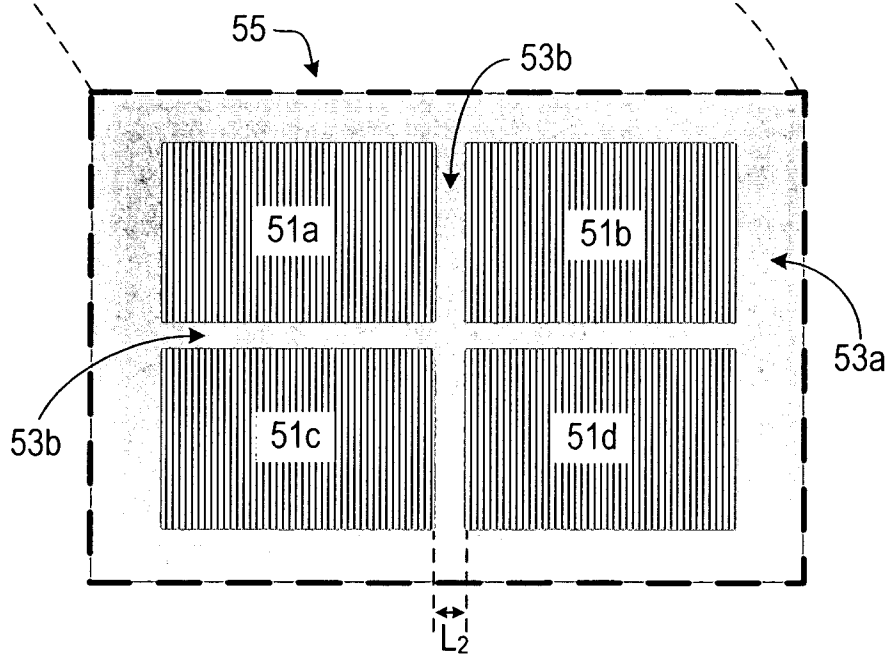
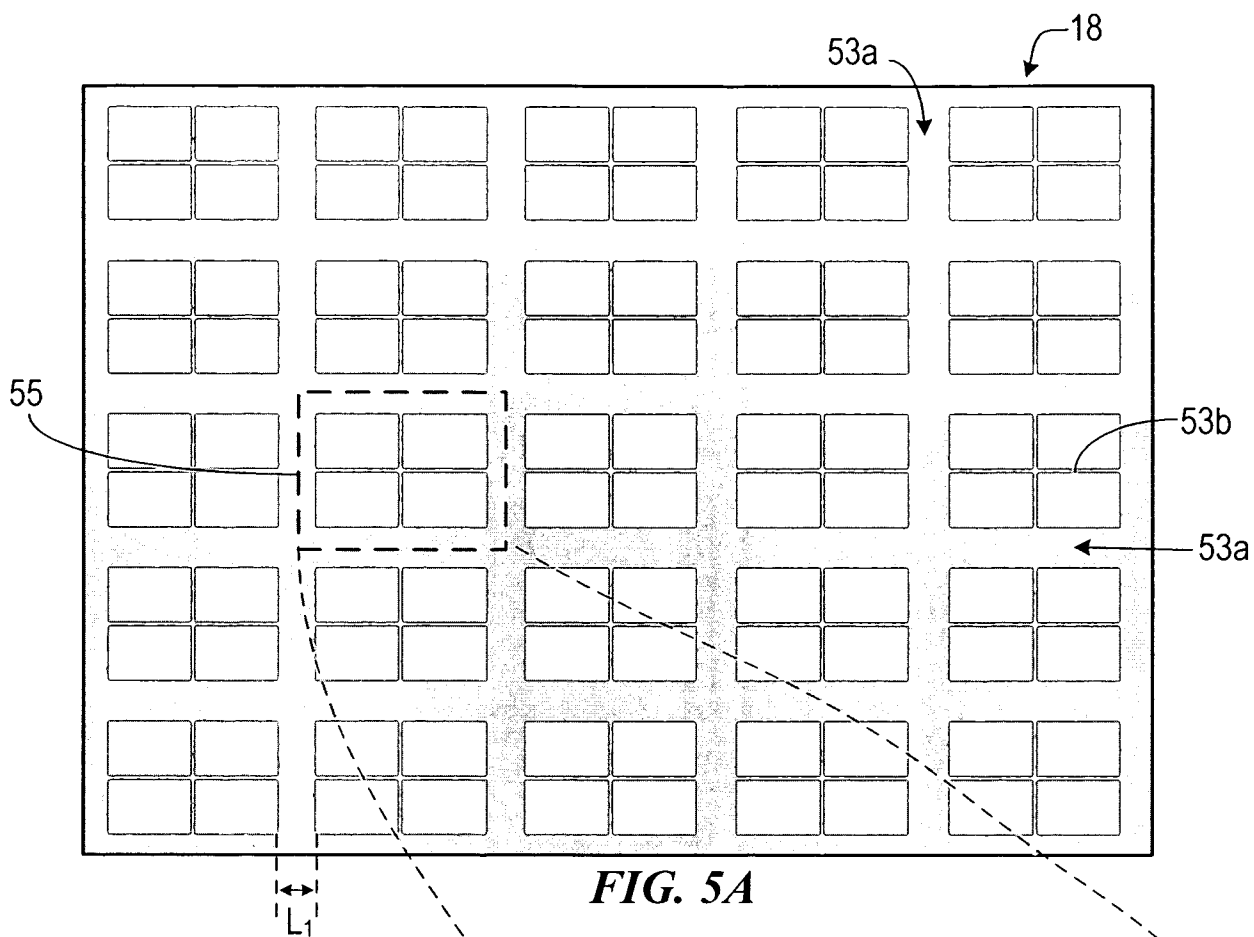


**FIG. 4A**



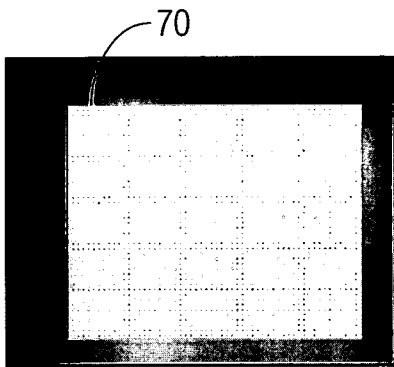
**FIG. 4B**

3/8

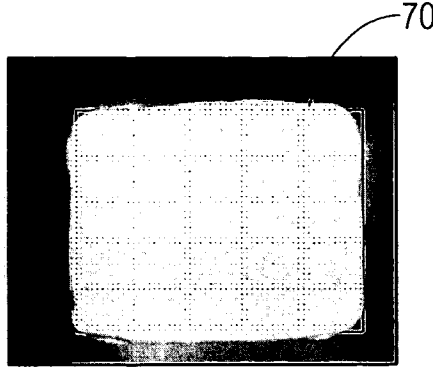




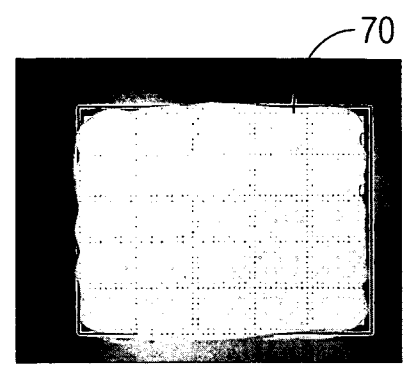
4/8



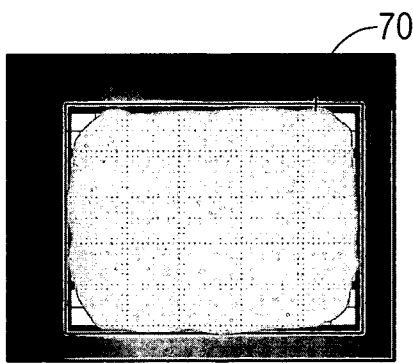
**FIG. 6A**



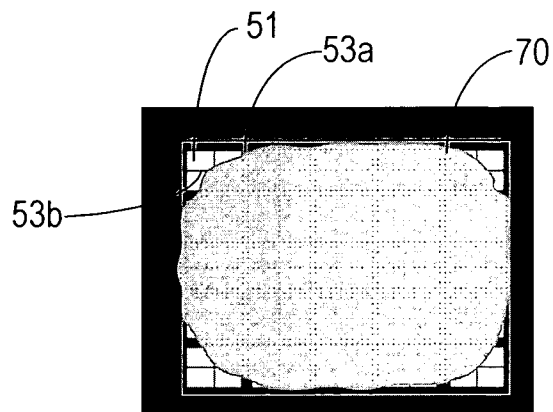
**FIG. 6B**



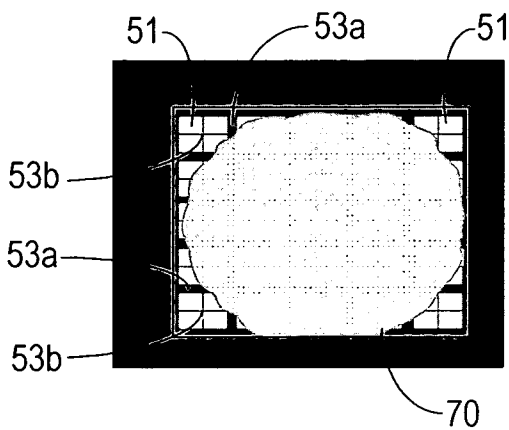
**FIG. 6C**



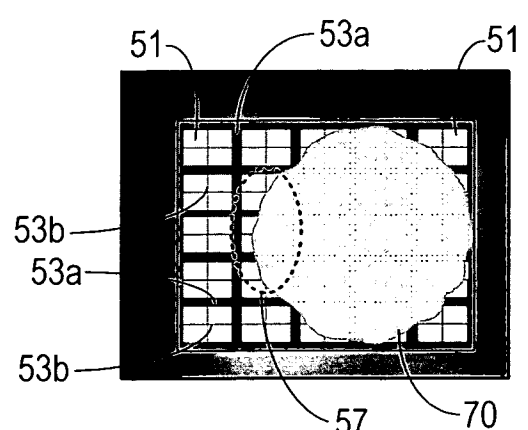
**FIG. 6D**



**FIG. 6E**

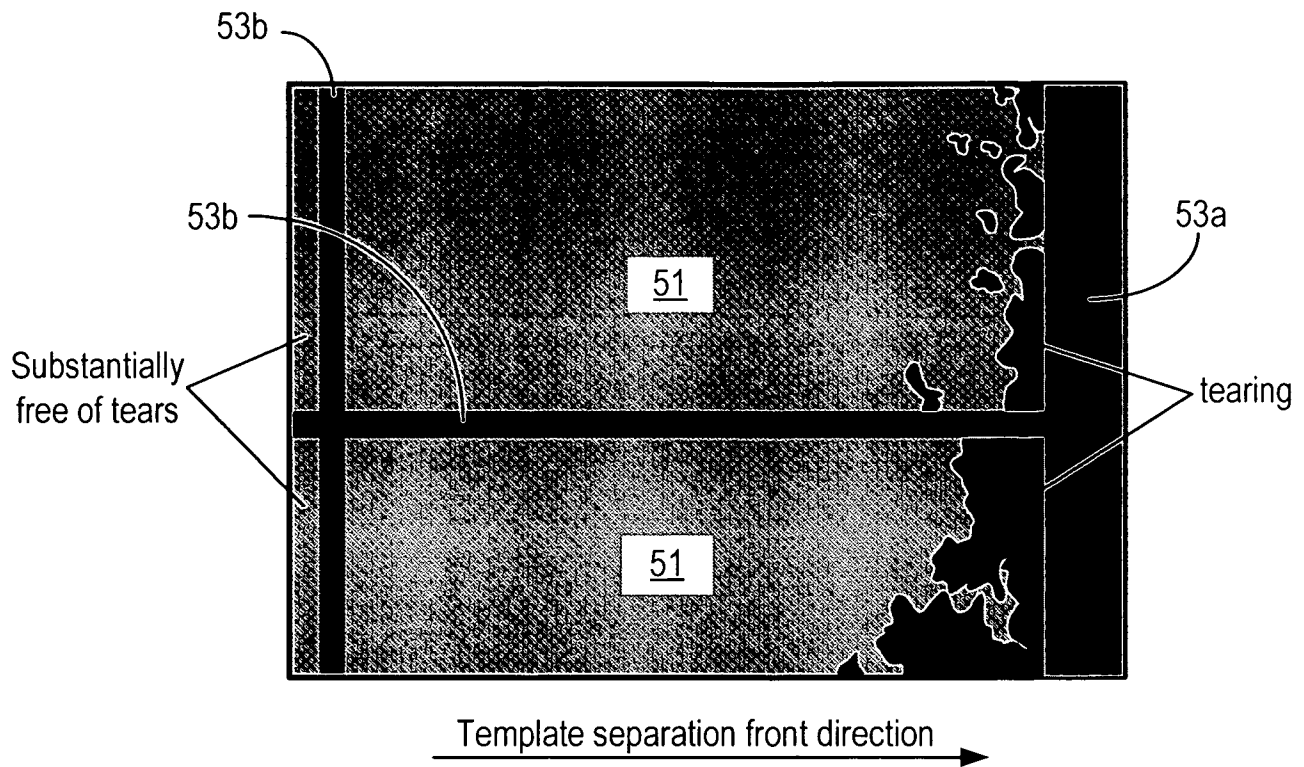


**FIG. 6F**

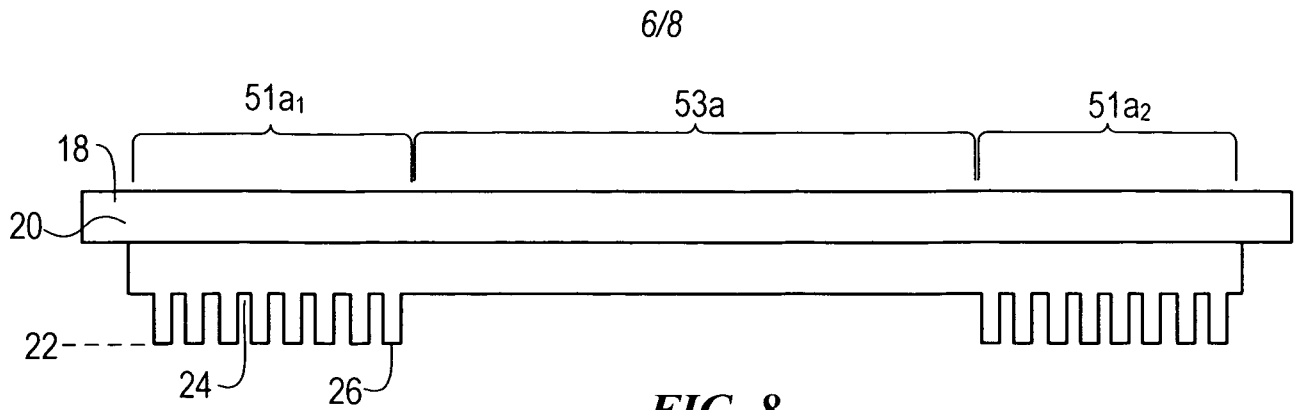
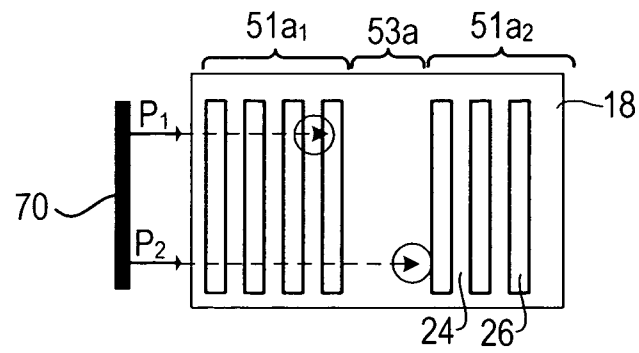
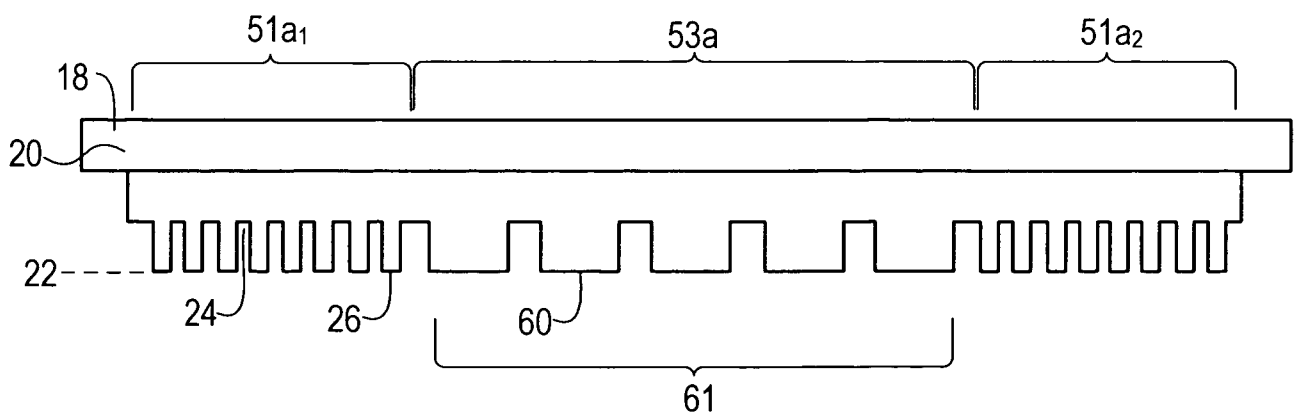


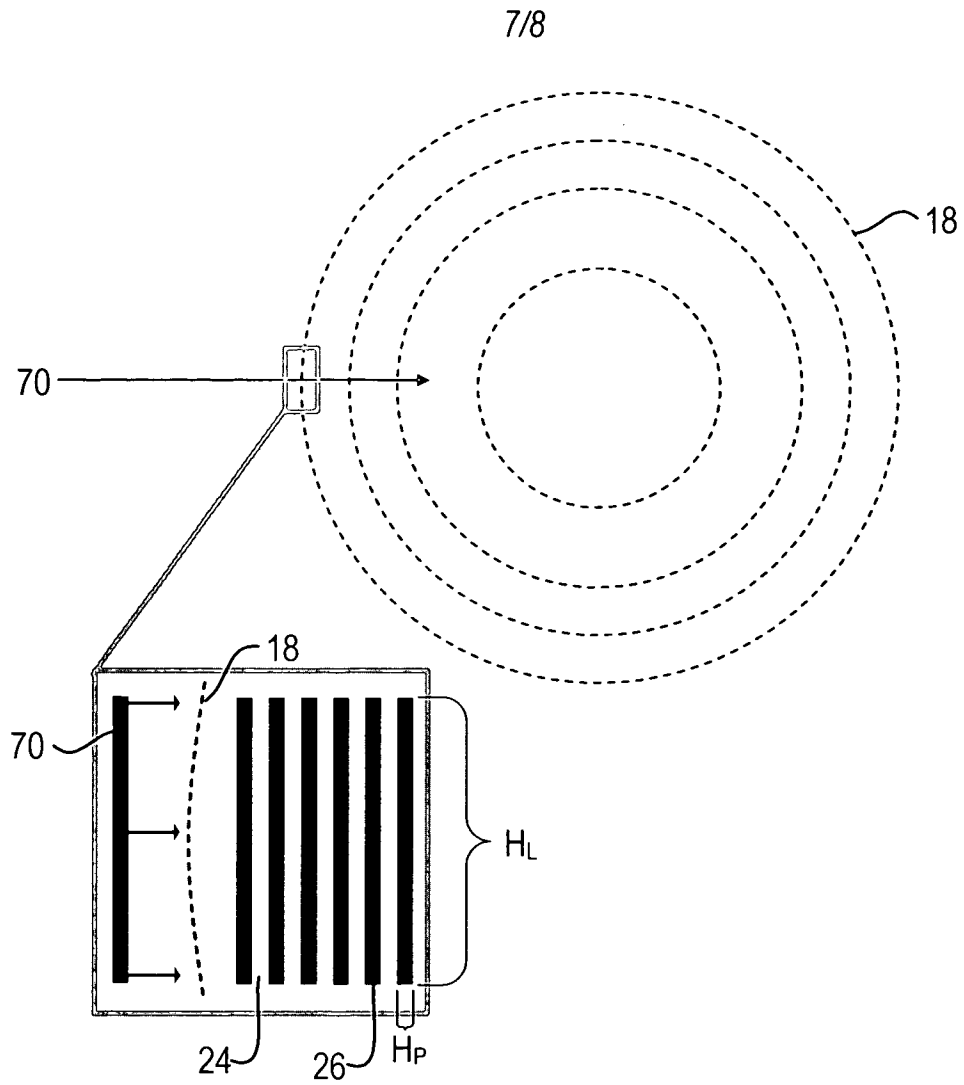
**FIG. 6G**

5/8

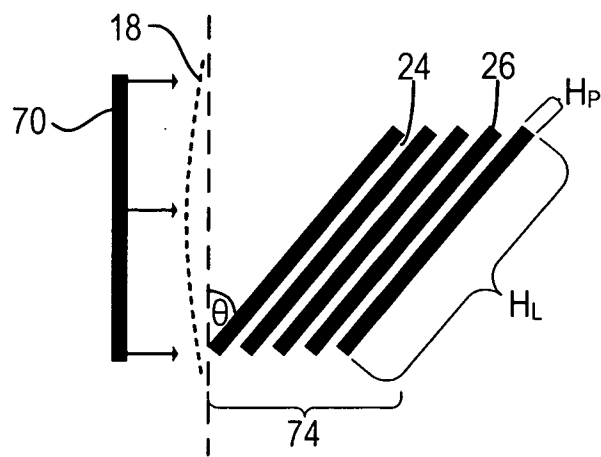


**FIG. 7**

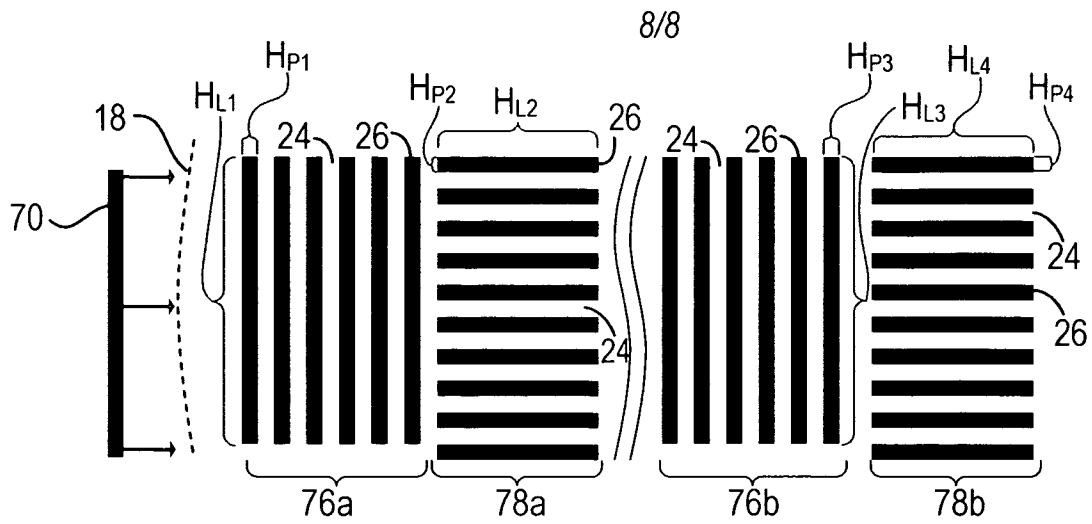
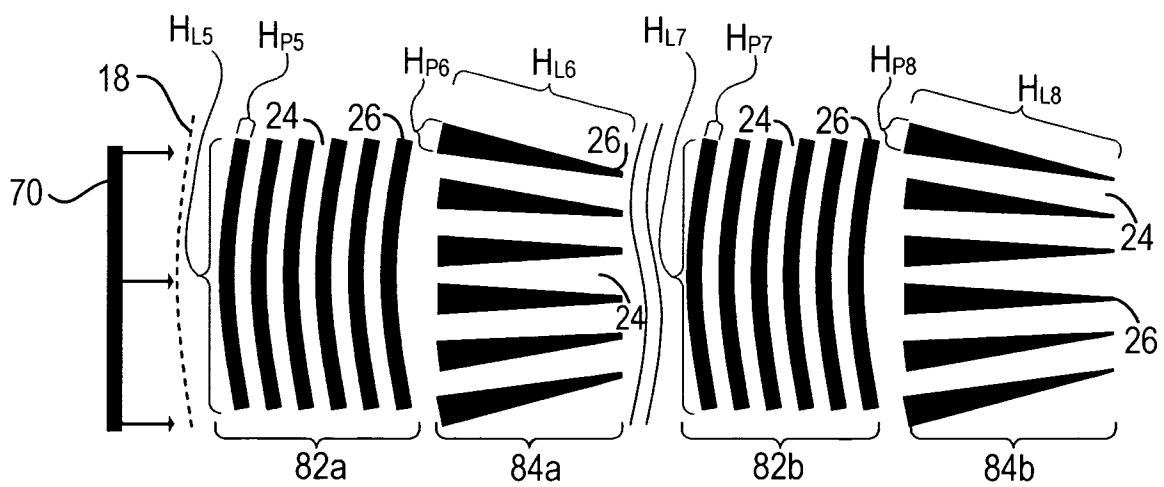
**FIG. 8****FIG. 9****FIG. 10**



**FIG. 11**



**FIG. 12**

**FIG. 13****FIG. 14**

## INTERNATIONAL SEARCH REPORT

International application No

PCT/US2009/005692

**A. CLASSIFICATION OF SUBJECT MATTER**  
INV. G03F7/00

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**Minimum documentation searched (classification system followed by classification symbols)  
G03F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, INSPEC

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	LANDIS S ET AL: "Stamp design effect on 100 nm feature size for 8 inch NanoImprint lithography" NANOTECHNOLOGY, IOP, BRISTOL, GB, vol. 17, no. 10, 28 May 2006 (2006-05-28), pages 2701-2709, XP020103747 ISSN: 0957-4484 page 2702, column 1, lines 17-31; figure 2	1-4, 6-10, 14-17
X	US 2008/203271 A1 (OKINAKA MOTOKI [JP] ET AL) 28 August 2008 (2008-08-28) figure 3A	1
X	DE 201 22 179 U1 (UNIV TEXAS [US]) 16 September 2004 (2004-09-16) paragraphs [0088], [0089]; figure 4 ----- -/--	1

☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

\* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&amp;" document member of the same patent family

Date of the actual completion of the international search

11 January 2010

Date of mailing of the international search report

18/01/2010

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel. (+31-70) 340-2040,  
Fax: (+31-70) 340-3016

Authorized officer

Müller-Kirsch, Lutz

## INTERNATIONAL SEARCH REPORT

International application No

PCT/US2009/005692

## C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2004/192041 A1 (JEONG JUN-HO [KR] ET AL) 30 September 2004 (2004-09-30) paragraph [0069]; figure 4 -----	1
A	US 2003/039897 A1 (MORITA TAKESHI [JP]) 27 February 2003 (2003-02-27) the whole document -----	4
A	US 2005/193364 A1 (KOTANI TOSHIYA [JP] ET AL) 1 September 2005 (2005-09-01) the whole document -----	4

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2009/005692

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2008203271 A1	28-08-2008	JP 2008207475 A	11-09-2008
DE 20122179 U1	16-09-2004	NONE	
US 2004192041 A1	30-09-2004	EP 1606834 A1	21-12-2005
		JP 2006521682 T	21-09-2006
		WO 2004086471 A1	07-10-2004
US 2003039897 A1	27-02-2003	JP 3556647 B2	18-08-2004
		JP 2003140319 A	14-05-2003
		US 2005287797 A1	29-12-2005
US 2005193364 A1	01-09-2005	NONE	