

Chucking System Comprising an Array of Fluid Chambers

[0001] The invention is directed to a chucking system comprising an array of fluid chambers.

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

[0003] An exemplary nano-fabrication technique is commonly referred to as imprint lithography. Exemplary imprint lithography processes are described in detail in numerous publications, such as United States patent application publication 2004/0065976 filed as United States patent application 10/264,960, entitled, "Method and a Mold to Arrange Features on a Substrate to Replicate Features having Minimal Dimensional Variability"; United States patent application publication 2004/0065252 filed as United States patent application 10/264,926, entitled "Method of Forming a Layer on a Substrate to Facilitate Fabrication of Metrology Standards"; and United States patent number 6,936,194, entitled "Functional Patterning Material for Imprint Lithography Processes," all of which are assigned to the assignee of the present invention.

[0004] The imprint lithography technique disclosed in each of the aforementioned United States patent application publications and United States patent includes formation of a relief pattern in a polymerizable layer and transferring a pattern corresponding to the relief pattern into an underlying substrate. The substrate may be positioned upon a stage to obtain a desired position to facilitate patterning

thereof. To that end, a mold is employed spaced-apart from the substrate with a formable liquid present between the mold and the substrate. The liquid is solidified to form a patterned layer that has a pattern recorded therein that is conforming to a shape of the surface of the mold in contact with the liquid. The mold is then separated from the patterned layer such that the mold and the substrate are spaced-apart. The substrate and the patterned layer are then subjected to processes to transfer, into the substrate, a relief image that corresponds to the pattern in the patterned layer.

[0005] There is still a need for an improved chucking system for easily changing the dimensions of the template as necessary.

[0006] This is achieved by the chucking system of claim 1. Preferred embodiments of the invention are characterized in the sub-claims.

[0007] Embodiments of the invention are now described with reference to the drawings in which:

[0008] Fig. 1 is a simplified side view of a lithographic system having a mold spaced-apart from a substrate, the substrate positioned upon a substrate chuck;

[0009] Fig. 2 is a top down view showing an array of droplets of imprinting material positioned upon a region of the substrate shown in Fig. 1;

[0010] Fig. 3 is a simplified side view of the substrate shown in Fig. 1, having a patterned layer positioned thereon;

[0011] Fig. 4 is a side view of the substrate chuck shown in Fig. 1;

[0012] Fig. 5 is a top down view of the substrate chuck shown in Fig. 1, showing a plurality of columns of pump systems in fluid communication with a plurality of fluid chambers of the substrate chuck;

[0013] Fig. 6 is a top down view of the substrate chuck shown in Fig. 1, showing a plurality of rows of pump systems in fluid communication with a plurality of fluid chambers of the substrate chuck;

[0014] Fig. 7 is an exploded view of a portion of the substrate chuck and substrate, both shown in Fig. 1

[0015] Fig. 8 is a flow diagram showing a method of patterning a region of the substrate shown in Fig. 1;

[0016] Fig. 9 is a side view of the mold and the substrate shown in Fig. 1, with a shape of the substrate being altered;

[0017] Fig. 10 is a side view of the mold and the substrate shown in Fig. 9, the mold being in contact with a portion of the droplets of imprint material shown in Fig. 2;

[0018] Figs. 11-13 are top down views showing the compression of the droplets shown in Fig. 2, employing the altered shape of the substrate shown in Fig. 9;

[0019] Fig. 14 is a side view of the mold and the substrate shown in Fig. 10, the substrate being positioned upon the substrate chuck;

[0020] Fig. 15 is a top down view showing the compression of the droplets in Fig. 2, employing the altered shape of the substrate shown in Fig. 10, in a further embodiment; and

[0021] Fig. 16 is a side view of the mold and the substrate shown in Fig. 1, the mold being partially separated from the substrate.

[0022] Referring to Fig. 1, a system 10 to form a relief pattern on a substrate 12 is shown. Substrate 12 may be coupled to a substrate chuck 14, described further below. Substrate 12 and substrate chuck 14 may be supported upon a stage 16. Further, stage 16, substrate 12, and substrate chuck 14 may be positioned on a base (not shown). Stage 16 may provide motion about the x and y axes.

[0023] Spaced-apart from substrate 12 is a template 18 having a mesa 20 extending therefrom towards substrate 12 with a patterning surface 22 thereon. Further, mesa 20 may be referred to as a mold 20. Mesa 20 may also be referred to as a nanoimprint mold 20. In a further embodiment, template 18 may be substantially absent of 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, siloxane polymers, borosilicate glass, fluorocarbon polymers, metal, and hardened sapphire. As shown, patterning surface 22 comprises features defined by a plurality of spaced-apart recesses 24 and protrusions 26. However, in a further embodiment, patterning surface 22 may be substantially smooth and/or planar. Patterning surface 22 may define an original pattern that forms the basis of a pattern to be formed on substrate 12. Template 18 may be coupled to a template chuck 28, template chuck 28 being any chuck including, but not limited to, vacuum, pin-type, groove-type, or electromagnetic, as described in United States patent 6,873,087 entitled "High-Precision Orientation Alignment and Gap Control Stages for Imprint Lithography

Processes” which is incorporated herein by reference. Further, template chuck 28 may be coupled to an imprint head 30 to facilitate movement of template 18, and therefore, mold 20.

[0024] System 10 further comprises a fluid dispense system 32. Fluid dispense system 32 may be in fluid communication with substrate 12 so as to deposit polymeric material 34 thereon. System 10 may comprise any number of fluid dispensers, and fluid dispense system 32 may comprise a plurality of dispensing units therein. Polymeric material 34 may be positioned upon substrate 12 using any known technique, e.g., drop dispense, spin-coating, dip coating, chemical vapor deposition (CVD), physical vapor deposition (PVD), thin film deposition, thick film deposition, and the like. As shown in Fig. 2, polymeric material 34 may be deposited upon substrate 12 as a plurality of spaced-apart droplets 36, defining a matrix array 38. In an example, each of droplets 36 may have a unit volume of approximately 1-10 picoliters. Droplets 36 of matrix array 38 may be arranged in five columns c_1 - c_5 and five rows r_1 - r_5 . However, droplets 36 may be arranged in any two-dimensional arrangement on substrate 12. Typically, polymeric material 34 is disposed upon substrate 12 before the desired volume is defined between mold 20 and substrate 12. However, polymeric material 34 may fill the volume after the desired volume has been obtained.

[0025] Referring to Figs. 1-3, system 10 further comprises a source 40 of energy 42 coupled to direct energy 42 along a path 44. Imprint head 30 and stage 16 are configured to arrange mold 20 and substrate 12, respectively, to be in superimposition and disposed in path 44. 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 polymeric material 34. More specifically, droplets 36 may ingress and fill recesses 24. The time required for droplets 36 to fill the pattern defined by patterning surface 22 may be defined as the “fill time” of mold 20. After the desired volume is filled with polymeric material 34, source 40 produces energy 42, e.g., broadband ultraviolet radiation that causes polymeric material 34 to solidify and/or cross-link conforming to the shape of a surface 46 of substrate 12 and patterning surface 22, defining a patterned layer 48 on substrate 12. Patterned layer 48 may comprise a residual layer 50 and a plurality of features shown as protrusions 52 and recessions 54. System 10 may be regulated by a processor 56 that is in data

communication with stage 16, imprint head 30, fluid dispense system 32, and source 40, operating on a computer readable program stored in memory 58.

[0026] Referring to Figs. 1 and 4-6, as mentioned above, system 10 comprises substrate chuck 14. Substrate chuck 14 is adapted to retain substrate 12 employing vacuum techniques. Substrate chuck 14 comprises a chuck body 60 having first 62 and second 64 opposed sides. A side, or edge, surface 66 extends between first 62 and second 64 opposed sides. First side 62 comprises a plurality of fluid chambers 68. As shown, substrate chuck 14 comprises fluid chambers 68a – 68u; however, in a further embodiment, substrate chuck 14 may comprise any number of fluid chambers. As shown, fluid chambers 68a – 68u may be positioned as an array arranged in five columns a₁-a₅ and five rows b₁-b₅. However, fluid chambers 68 may be arranged in any two-dimensional arrangement in chuck body 60. For simplicity of illustration, columns a₁-a₅ and rows b₁-b₂ are shown separately in Figs. 5 and 6, respectively.

[0027] Referring to Figs. 4-6, each of fluid chambers 68 comprises a first recess 70 and a second recess 72, spaced-apart from first recess 70, defining a support region 74 and a second support region 76. Second support region 76 cinctures second recess 72. First support region 74 cinctures second support region 76 and first and second recesses 70 and 72. Formed in chuck body 60 are a plurality of throughways 78 and 80 to place each of fluid chambers 68 in fluid communication with a pump system 82 and 84, respectively. More specifically, each first recess 70 of fluid chambers 68 may be in fluid communication with pump system 82 via throughway 78 and each second recess 72 may be in fluid communication with pump system 84 via throughway 80. Each of pump systems 82 and 84 may include one or more pumps therein.

[0028] Referring to Figs. 4 and 5, each first recess 70 of fluid chambers 68 in a column a₁-a₅ of fluid chambers 68 may be in fluid communication with pump system 82 via throughway 78. More specifically, first recess 70 of fluid chambers 68d, 68i, and 68n in column a₁ may be in fluid communication with a pump system 82a via a throughway 78a; first recess 70 of fluid chambers 68a, 68e, 68j, 68o, and 68s in column a₂ may be in fluid communication with a pump system 82b via a throughway 78b; first recess 70 of fluid chambers 68b, 68f, 68k, 68p, and 68t in column a₃ may be in fluid communication with a pump system 82c via a throughway 78c; first recess 70 of fluid chambers 68c, 68g, 68l, 68q, and 68u in column a₄ may be

in fluid communication with a pump system 82d via a throughway 78d; and first recess 70 of fluid chambers 68h, 68m, and 68r in column a₅ may be in fluid communication with a pump system 82e via a throughway 78e.

[0029] Referring to Figs. 4 and 6, furthermore, each second recess 72 of fluid chambers 68 in a row b₁-b₅ may be in fluid communication with pump system 84 via throughway 80. More specifically, second recess 72 of fluid chambers 68a, 68b, and 68c in row b₁ may be in fluid communication with a pump system 84a via a throughway 80a; second recess 72 of fluid chambers 68d, 68e, 68f, 68g, and 68h in row b₂ may be in fluid communication with a pump system 84b via a throughway 80b; second recess 72 of fluid chambers 68i, 68j, 68k, 68l, and 68m in row b₃ may be in fluid communication with a pump system 84c via a throughway 80c; second recess 72 of fluid chambers 68n, 68o, 68p, 68q, and 68r in row b₄ may be in fluid communication with a pump system 84d via a throughway 80d; and second recess 72 of fluid chambers 68s, 68t, and 68u may be in fluid communication with a pump system 84e via a throughway 80e.

[0030] Referring to Figs. 1 and 4-6, when substrate 12 is positioned upon substrate chuck 14, substrate 12 rests against first surface 62 of chuck body 60, covering fluid chambers 68, and more specifically, covering first and second recesses 70 and 72 of each of fluid chambers 68. More specifically, each first recess 70 of fluid chambers 68 and a portion of substrate 12 in superimposition therewith define a first chamber 86; and each second recess 72 of fluid chambers 68 and a portion of substrate 12 in superimposition therewith define a second chamber 88. Furthermore, pump system 82 operates to control a pressure/vacuum within first chamber 86 and pump system 84 operates to control a pressure/vacuum within second chamber 88. The pressure/vacuum within first chambers 86 and 88 may be established to maintain the position of substrate 12 to reduce, if not avoid, separation of substrate 12 from substrate chuck 14 while altering a shape of substrate 12, described further below. Pump systems 82 and 84 may be in data communication with processor 56, operating on a computer readable program stored in memory 58 to control pump systems 82 and 84.

[0031] Referring to Figs. 4 and 5, more specifically, pump system 82a operates to control a pressure/vacuum within first chamber 86 of fluid chambers 68d, 68i, and 68n in column a₁; pump system 82b operates to control a pressure/vacuum

within first chamber 86 of fluid chambers 68a, 68e, 68j, 68o, and 68s in column a₂; pump system 88c operates to control a pressure/vacuum within first chamber 86 of fluid chambers 68b, 68f, 68k, 68p, and 68t in column a₃; pump system 88d operates to control a pressure/vacuum within first chamber 86 of fluid chambers 68c, 68g, 68l, 68q, and 68u in column a₄; and pump system 88e operates to control a pressure/vacuum within first chamber 86 of fluid chambers 68h, 68m, and 68r in column a₅.

[0032] Referring to Figs. 4 and 6, furthermore, pump system 84a operates to control a pressure/vacuum within second chamber 88 of fluid chambers 68a, 68b, and 68c in row b₁; pump system 84b operates to control a pressure/vacuum within second chamber 88 of fluid chambers 68d, 68e, 68f, 68g, and 68h in row b₂; pump system 84c operates to control a pressure/vacuum within second chamber 88 of fluid chambers 68i, 68j, 68k, 68l, and 68m in row b₃; pump system 84d operates to control a pressure/vacuum within second chamber 88 of fluid chambers 68n, 68o, 68p, 68q, and 68r in row a₄; and pump system 84e operates to control a pressure/vacuum within second chamber 88 of fluid chambers 68s, 68t, and 68u in row b₅.

[0033] Referring to Figs. 4-7, each of fluid chambers 68 may have 1) a chucked state associated therewith or 2) a non-chucked/bowed state associated therewith, depending upon the application desired, described further below. More specifically, as mentioned above, first and second chambers 86 and 88 are associated with first and second recesses 70 and 72, respectively. To that end, a force exerted upon a portion of substrate 12 may be dependent upon, *inter alia*, a magnitude of the areas of first and second recesses 70 and 72 in superimposition with the portion of substrate 12 and a magnitude of the pressure/vacuum within first and second chambers 86 and 88 in superimposition with the portion of substrate 12. More specifically, for a portion 90 of substrate 12 in superimposition with a subset of fluid chambers 68, the force exerted upon portion 90 is a combination of a force F₁ exerted upon a sub-portion 92 of portion 90 in superimposition with first recess 70 / first chamber 86 and a force F₂ exerted upon a sub-portion 94 of portion 90 in superimposition with second recess 72 / second chamber 88. As shown, both force F₁ and F₂ are in a direction away from substrate 12. However, forces F₁ and F₂ may be in a direction towards substrate 12. Further, forces F₁ and F₂ may be in opposite

directions. To that end, force F_1 exerted upon sub-portion 92 may be defined as follows:

$$F_1 = A_1 \times P_1 \quad (1)$$

where A_1 is the area of first recess 70 and P_1 is the pressure/vacuum associated with first chamber 86; and force F_2 exerted upon sub-portion 94 may be defined as follows:

$$F_2 = A_2 \times P_2 \quad (2)$$

where A_2 is the area of second recess 72 and P_1 is the pressure/vacuum associated with second chamber 88. Forces F_1 and F_2 associated with fluid chamber 68 may be referred to collectively as the chuck force F_c exerted by substrate chuck 14 upon substrate 12.

[0034] Referring to Figs. 1 and 4-6, to that end, it may be desired to have differing fluid chambers 68 have differing states therewith depending upon, *inter alia*, the spatial relationship between droplets 36, substrate 12, and mold 20. The state of first and second chambers 86 and 88 depend upon, *inter alia*, the direction of forces F_1 and F_2 . More specifically, for force F_1 being in a direction towards substrate 12, first chamber 86 is in the pressure state; for force F_1 being in a direction away from substrate 12, first chamber 86 is in the vacuum state; for force F_2 being in a direction towards substrate 12, second chamber 88 is in the pressure state; and for force F_2 being in a direction away from substrate 12, second chamber 88 is in the vacuum state.

[0035] To that end, as a result of the possibility of first and second chambers 86 and 88 each having two differing states associated therewith, fluid chambers 68 may have one of four combinations associated therewith. Shown below in table 1 are the four combinations of vacuum/pressure within first and second chamber 86 and 88 and the resulting state of fluid chambers 68.

Combination	First Chamber 86	Second Chamber 88	State of Fluid Chamber 68
1	Vacuum	Vacuum	Chucked
2	Vacuum	Pressure	Chucked

3	Pressure	Vacuum	Chucked
4	Pressure	Pressure	Non-Chucked / Bowed

Table 1

[0036] In the first and fourth combinations, first and second chambers 86 and 88 have the same state associated therewith. More specifically, in the first combination, first chamber 86 is in the vacuum state and second chamber 88 is in the vacuum state, and as a result, fluid chamber 68 has a chucked state associated therewith. Further, in the fourth combination, first chamber 86 is in the pressure state and second chamber 88 is in the pressure state, and as a result, fluid chamber 68 has a non-chucked/bowed state associated therewith.

[0037] In the second and third combinations, first and second chambers 86 and 88 have differing states associated therewith. However, fluid chamber 68 has a chucked state associated therewith. To that end, the ratio of the areas A_1 and A_2 of first and second recesses 70 and 72 is such that for a given pressure K_p and a given vacuum K_v associated with first and second chambers 86 and 88, a magnitude of a force of forces F_1 and F_2 associated with the vacuum state of first and second chambers 86 and 88 is greater than a magnitude of the force of the remaining forces F_1 and F_2 associated with the pressure state of first and second chambers 86 and 88. To that end, in the second combination mentioned above, first chamber 86 is in the vacuum state and second chamber 88 is in the pressure state.

[0038] For fluid chamber 68 to be in the vacuum state:

$$|F_1| > |F_2| \quad (3)$$

and thus, employing equations (1) and (2) mentioned above:

$$|A_1 \times K_v| > |A_2 \times K_p| \quad (4)$$

and thus the ratio of areas A_1 and A_2 of first and second recesses 70 and 72, respectively, is:

$$A_1 / A_2 > |K_p / K_v|. \quad (5)$$

[0039] In the third combination mentioned above, first chamber 86 is in the pressure state and second chamber 88 is in the vacuum state. To that end, for fluid chamber 68 to be in the vacuum state:

$$|F_2| > |F_1| \quad (6)$$

and thus, employing equations (1) and (2) mentioned above:

$$|A_2 \times K_v| > |A_1 \times K_p| \quad (7)$$

and thus the ratio of areas A_1 and A_2 of first and second recesses 70 and 72, respectively, is:

$$A_1 / A_2 < |K_v / K_p|. \quad (8)$$

[0040] To that end, it is apparent for fluid chamber 68 to have a vacuum state associated therewith when first and second chambers 86 and 88 are in differing states, the areas A_1 and A_2 of first and second recesses 70 and 72, respectively, may be defined as follows:

$$|K_p / K_v| < A_1 / A_2 < |K_v / K_p|. \quad (9)$$

[0041] In an example, K_p may be approximately 40 kPa and K_v may be approximately -80 kPa, and thus, the ratio of the areas A_1 to A_2 may be defined as follows:

$$0.5 < A_1 / A_2 < 2. \quad (10)$$

[0042] Furthermore, a magnitude of the pressure within a fluid chamber 68 being in the non-chucked/bowed state may be varied. More specifically, processor 56, operating on a computer readable program stored in memory 58, may vary a magnitude of the pressure within first and second chambers 86 and 88 via pump

systems 82 and 88, respectively, as a result of being in electrical communication with pump systems 82 and 84.

[0043] Referring to Figs. 1-3, as mentioned above, a distance between mold 20 and substrate 12 is varied such that a desired volume is defined therebetween that is filled by polymeric material 34. Furthermore, after solidification, polymeric material 34 conforms to the shape of surface 46 of substrate 12 and patterning surface 22, defining patterning layer 48 on substrate 12. To that end, in a volume 96 defined between droplets 36 of matrix array 38, there are gases present. The gases and/or gas pockets may be such gases including, but not limited to air, nitrogen, carbon dioxide, and helium. The gases between substrate 12 and mold 20 may result from, *inter alia*, a planarity of substrate 12 and mold 20. To that end, it may be desired to reduce the fill time, mentioned above, of mold 20. The fill time is dependent upon, *inter alia*, the time required for the gases and/or gas pockets between substrate 12 and mold 20 and within patterning layer 48 to evacuate from between substrate 12 and mold 20 and/or dissolve into polymeric material 34 and/or diffuse into polymeric material 34. To that end, a method and a system of minimizing, if not preventing, trapping of gas between mold 20 and substrate 12 are described below.

[0044] Referring to Figs. 1 and 8, a method of expelling gas between substrate 12 and mold 20 is shown. More specifically, at step 100, as mentioned above, polymeric material 34 may be positioned on substrate 12 by drop dispense, spin-coating, dip coating, chemical vapor deposition (CVD), physical vapor deposition (PVD), thin film deposition, thick film deposition, and the like. In a further embodiment, polymer material 34 may be positioned on mold 20.

[0045] Referring to Figs. 5, 6, 8, and 9, at step 102, a shape of substrate 12 may be altered such that a distance d_1 defined between mold 20 and substrate 12 at a center sub-portion of substrate 12 is less than a distance defined between mold 20 and substrate 12 at remaining portions of substrate 12. In an example, distance d_1 is less than a distance d_2 , distance d_2 being defined at an edge of substrate 12. In a further embodiment, the distance d_1 may be defined at any desired location of substrate 12. The shape of substrate 12 may be altered by controlling a pressure/vacuum within the plurality of fluid chambers 68. More specifically, fluid chambers 68 in superimposition with a portion 98 of substrate 12 are in a non-chucked/bowed state to bow portion 98 of substrate 12 towards mold 20 and away from substrate chuck 14.

Further, concurrently with fluid chambers 68 in superimposition with a portion 98 of substrate 12 being in the non-chucked/bowed state, the remaining fluid chambers 68 in superimposition with a portion 99 of substrate 12 are in a chucked state to retain substrate 12 upon substrate chuck 14.

[0046] Referring to Figs. 7, 10, and 11, at step 104, as described above with respect to Fig. 1, either imprint head 30, shown in Fig. 1, stage 16, or both, may vary distance d_1 , shown in Fig. 9, such that a sub-portion of mold 20 contacts a sub-portion of droplets 36. As shown, a center sub-portion of mold 20 contacts a sub-portion of droplets 36 prior to the remaining portions of mold 20 contacting the remaining droplets of droplets 36. However, in a further embodiment, any portion of mold 20 may contact droplets 36 prior to remaining portions of mold 20. To that end, as shown mold 20 contacts all of droplets 36 associated with column c_3 , shown in Fig. 2, substantially concurrently. This causes droplets 36 to spread and produce contiguous liquid sheet 120 of polymeric material 34. Edges 122a and 122b of liquid sheet 120 define liquid-gas interfaces 124a and 124b, respectively, that function to push gases in volume 96 towards edges 128a, 128b, 128c, and 128d. Volume 96 between droplets 36 in columns c_1 - c_5 define gas passages through which gas may be pushed to edges 128a, 128b, 128c, and 128d. As a result, liquid-gas interfaces 124a and 124b in conjunction with the gas passages reduces, if not prevents, trapping of gases in liquid sheet 120.

[0047] Referring to Figs. 4-6 and 8, at step 106, the shape of substrate 12 may be further altered as the distance d_1 is further reduced such that the desired volume defined between mold 20 and substrate 12 may be filled by polymeric material 34, as described above with respect to Fig. 1. More specifically, the shape of substrate 12 may be altered via fluid chambers 68 in combination with decreasing distance d_1 via imprint head 30, stage 16, or both. More specifically, as mentioned above, the magnitude of the pressure within first and second chambers 86 and 88 of fluid chambers 68 in superimposition with portion 98 of substrate 12, shown in Fig. 9, may be varied. To that end, as the distance d_1 , shown in Fig. 9, is decreased, the magnitude of the pressure within first and second chambers 86 and 88 of fluid chambers 68 in superimposition with portion 98 of substrate 12, shown in Fig. 9, may be decreased. As a result of decreasing distance d_1 , shown in Fig. 9, and decreasing the aforementioned pressure in first and second chambers 86 and 88 of the fluid

chambers 68 in superimposition with portion 98 of substrate 12, shown in Fig. 9, polymeric material 34 associated with droplets 36 in column c_2 and c_4 , shown in Fig. 2, spread to become included in contiguous fluid sheet 120, as shown in Fig. 12. Distance d_1 , shown in Fig. 9, may be further reduced in combination with decreasing the magnitude of the pressure within first and second chambers 86 and 88 of fluid chambers 68 in superimposition with portion 98 of substrate 12, shown in Fig. 9, such that mold 20 subsequently comes into contact with droplets 36 associated with columns c_1 and c_5 such that polymeric material 34 associated therewith spreads to become included in contiguous sheet 120, as shown in Fig. 13. In a further embodiment, the pressure within first and second chambers 86 and 88 of fluid chambers 68 in superimposition with portion 98 of substrate 12 may be reduced such that portion 98 of substrate 12 is positioned upon substrate chuck 14, as shown in Fig. 14. In still a further embodiment, first and second chambers 86 and 88 of fluid chambers 68 in superimposition with portion 98 of substrate 12 may have a vacuum therein subsequent to spreading of droplets 36.

[0048] Referring to Figs. 8 and 13, as can be seen, interfaces 124a and 124b have moved towards edges 128c and 128a, respectively, so that there is an unimpeded path for the gases in the remaining volume 96, shown in Fig. 11, to travel thereto. This allows gases in volume 96, shown in Fig. 11, to egress from between mold 20 and substrate 12 vis-à-vis edges 128a, 128b, 128c, and 128d. In this manner, the trapping of gases and/or gas pockets between substrate 12 and mold 20 and within patterning layer 48, shown in Fig. 3, is minimized, if not prevented.

[0049] Referring to Figs. 1 and 8, at step 108, as mentioned above with respect to Fig. 1, polymeric material 34 may be then solidified and/or cross-linked, defining patterned layer 48, shown in Fig. 3. Subsequently at step 110, mold 20 may be separated from patterned layer 48.

[0050] Referring to Figs. 1, 8 and 15, as described above, the shape of substrate 12 may be altered along a first direction. However, in a further embodiment, the shape of substrate 12 may be altered concurrently in first and second directions, with the second direction extending orthogonal to the first direction. More specifically, substrate 12 may be altered such that a center sub-portion of substrate 12 contacts mold 20, and thus, a center sub-portion of droplets 36 contacts mold 20 prior to the remaining droplets of droplets 36 contacting mold 20, as described above with

respect to Fig. 10. This causes droplets 36 to spread and to produce contiguous liquid sheet 120 of polymeric material 34, defining continuous liquid-gas interface 124 that functions to push gases in volume 96 outward radially. In an example, liquid sheet 120 may have a circular or circular-like expansion of liquid-gas interface 124 to push gases in volume 96 towards edges 128a, 128b, 128c, and 128d outward radially. However, in a further embodiment, the shape of substrate 12 may be altered in any direction to produce liquid sheet 120 with any geometric shape, i.e. spherical, cylindrical, etc., desired to facilitate pushing gases in volume 96 towards edges 128a, 128b, 128c, and 128d outward radially to minimize, if not prevent, trapping of gas and/or gas pockets between substrate 12 and mold 120 and within patterning layer 48, as shown in Fig. 3. In a further embodiment, a subset of rows or columns of first and second chambers 86 and 88, respectively, may be have no pressure/vacuum created therein.

[0051] Referring to Fig. 16, in a further embodiment, substrate chuck 14 may be further employed to facilitate separation between mold 20 and patterned layer 48 positioned upon substrate 12. More specifically, separation of mold 20 from patterned layer 48 is achieved by application of a separation force F_s to template 18 and mold 20. Separation force F_s is of sufficient magnitude to overcome adhesion forces between mold 20 and patterned layer 48 and the resistance of substrate 12 to strain (deformation). It is believed that deformation of a portion of substrate 12 facilitates separation of mold 20 from patterned layer 48. To that end, it may be desired to minimize a magnitude of the separation force F_s to achieve separation of mold 20 from patterned layer 48. Minimizing the magnitude of the separation force F_s may, *inter alia*, facilitate alignment between mold 20 and substrate 12, increase a ratio of template patterning area versus total template area, and minimize probability of structural compromise of template 18, mold 20, substrate 12, and patterned layer 48.

[0052] To that end, as mentioned above, a magnitude of the pressure within fluid chambers 68 may be varied. To that end, during separation of mold 20 from patterned layer 48, fluid chambers 68 in superimposition with a portion 13 of substrate 12 may be in the non-chucked/bowed state. As a result, fluid chambers 68 in superimposition with portion 13 of substrate 12 may exert chuck force F_c , forces F_1 and F_2 , shown in Fig. 7, in substantially the same direction as the direction of the

separation force F_s . As a result, the magnitude of the separation force F_s required to separate mold 20 from patterned layer 48 may be reduced. More specifically, the magnitude of chuck force F_c in superimposition with portion 13 of substrate 12 is established to facilitate strain (deformation) of portion 13 of substrate 12 in response to separation force F_s . It should be noted that the magnitude of chuck force F_c in superimposition with portion 13 of substrate 12 may have any value desired such that portions of substrate 12 outside of portion 13 are retained upon substrate chuck 14 when the same is subjected to separation force F_s .

[0053] Referring to Fig. 1, in still a further embodiment, the above-mentioned method of bending of substrate 12 via substrate chuck 14 may be analogously applied to template 18/mold 20. More specifically, template 18/mold 20 may be positioned upon substrate chuck 14 to facilitate bending thereof in substantially the same method as described above with respect to substrate 12. To that end, template 18/mold 20 may have a thickness of 1 mm to facilitate bending thereof. In still a further embodiment, substrate 12 may be altered employing a plurality of actuators in lieu of, or in combination with, substrate chuck 14.

[0054] The embodiments of the present invention described above are exemplary. Many changes and modifications may be made to the disclosure recited above, while remaining within the scope of the invention. Therefore, the scope of the invention should not be limited by the above description, but instead should be determined with reference to the appended claims along with their full scope of equivalents

Claims

1. A chucking system to hold a substrate, said system comprising:
a chuck body having first and second opposed sides, said first side including a fluid chamber,
said fluid chamber comprising first and second spaced-apart recesses, defining first and second spaced-apart support regions, with said first support region cincturing said second support region and said first and second recesses, and said second support region cincturing said second recess, with said substrate resting against said first and second support regions,
with said first recess and a portion of said substrate in superimposition therewith defining a first chamber and said second recess and a portion of said substrate in superimposition therewith defining a second chamber;
with said first chamber and said second chamber being in fluid communication with a differing source of fluid to control a flow of fluid in said fluid chambers.
2. The chucking system as recited in claim 1, further comprising:
a pressure control system in fluid communication with said first and second chambers to control a pressure within said first and second chambers such that one of said first and second chambers has a positive pressure therein and the remaining chamber of said first and second chambers has a negative pressure therein, wherein for a given positive pressure within one of said first and second chambers and a negative pressure within the remaining chamber of said first and second chambers, a ratio of an area between said first and second recesses is such that said fluid chamber exerts a negative force upon a portion of said substrate in superimposition with said fluid chamber.
3. The chucking system as recited in claim 1 or 2 further including a plurality of fluid chambers.

4. The chucking system as recited in claim 1, 2 or 3 further including a first and second throughways to place said first and second chambers, respectively, in fluid communication with said pressure control system.
5. The chucking system as recited in any of the preceding claims wherein said pressure control system comprises a plurality of sources of fluid.
6. The chucking system as recited in any of the preceding claims said system further including an array of fluid chambers arranged in rows and columns, with each column of said first chambers and each row of said second chambers are in fluid communication with a differing source of fluid of said plurality of sources of fluid to control a flow of fluid in said array of fluid chambers.
7. The chucking system as recited in claim 6 wherein each first chamber in a column of said fluid chambers is in fluid communication with a common fluid source.
8. The chucking system as recited in claim 6 wherein each second chamber in a row of said fluid chambers is in fluid communication with a common fluid source.
9. The chucking system as recited in claim 6 wherein each first chamber in a column of said fluid chambers is in fluid communication with a first common fluid source and wherein each second chamber in a row of said fluid chambers is in fluid communication with a second common fluid source differing from said first common fluid source.
10. The chucking system as recited in claim 6 wherein a fluid chamber of said array of fluid chambers is sealed from the remaining fluid chambers of said array of fluid chambers.
11. The chucking system as recited in claim 6 further including a plurality of throughways, with each column of said first chambers and each row of said second chambers being coupled to differing throughways to place said first and second chambers in fluid communication with said differing source of fluid.