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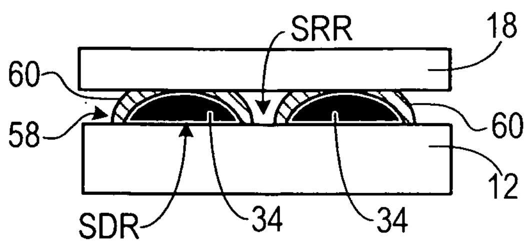

FIG. 7A

(57) Abstract: A template is treated to provide a surfactant rich region and a surfactant depleted region. A contact angle at the surfactant rich region may be greater than, less than, or substantially similar to a contact angle of the surfactant depleted region.

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CONTACT ANGLE ATTENUATIONS ON MULTIPLE SURFACES

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application priority to U.S. Patent Application Serial No. 12/336,821 filed December 17, 2008, and U.S. Provisional Patent Application Serial No. 61/014,574 filed on December 18, 2007, which are both hereby incorporated by reference herein.

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 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 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 herein.

[0004] An imprint lithography technique disclosed in each of the aforementioned U.S. patent publications and patent includes formation of a relief pattern in a formable (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 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 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 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 a lithographic system in accordance with an embodiment of the present invention.

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

[0008] FIGS. 3A-3C illustrate simplified side views of a template being treated with imprint fluid containing polymerizable material and surfactant liquid.

[0009] FIGS. 4A-4C illustrate simplified side views of a testing substrate having surfactant solution and imprint fluid deposited thereon.

[0010] FIGS. 5A-5C illustrate simplified side views of a testing substrate having solvent and imprint fluid deposited thereon.

[0011] FIG. 6 illustrates a flow chart of an exemplary method for providing suitable wetting characteristics between a template and a polymerizable material.

[0012] FIGS. 7A-7B illustrate a simplified side view and a top down view, respectively, of surfactant depleted regions SDR and surfactant rich regions SRR after imprinting using a first drop pattern.

[0013] FIG. 8 illustrates a flow chart of another exemplary method for providing suitable wetting characteristics between a template and a polymerizable material.

DETAILED DESCRIPTION

[0014] 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 including, but not limited to, vacuum, pin-type, groove-type, electrostatic, electromagnetic, and/or the like. Exemplary chucks are described in U.S. Patent No. 6,873,087, which is hereby incorporated by reference herein.

[0015] Substrate 12 and substrate chuck 14 may be further supported by stage 16. Stage 16 may provide motion along the x, y, and z axes. Stage 16, substrate 12, and substrate chuck 14 may also be positioned on a base (not shown).

[0016] Spaced-apart from substrate 12 is template 18. Template 18 may include 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. Alternatively, template 18 may be formed without mesa 20.

[0017] 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, 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 pattern to be formed on substrate 12.

[0018] Template 18 may be coupled to chuck 28. Chuck 28 may be configured as, but not limited to, vacuum, pin-type, groove-type, electrostatic, 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 herein. Further, chuck 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.

[0019] System 10 may further comprise 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 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 mixture as described in U.S. Patent No. 7,157,036 and U.S. Patent Publication No. 2005/0187339, both of which are hereby incorporated by reference herein.

[0020] Referring to FIGS. 1 and 2, system 10 may further comprise 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 processor 54 in communication with stage 16, imprint head 30, fluid dispense system 32, and/or source 38, and may operate on a computer readable program stored in memory 56.

[0021] 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 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., ultraviolet radiation, causing polymerizable material 34 to solidify and/or cross-link conforming to a shape of surface 44 of substrate 12 and patterning surface 22, defining 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 a thickness t_1 and residual layer having a thickness t_2.

[0022] 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 herein.

[0023] In another embodiment, the above-mentioned system and process may be employed using techniques including, but not limited to, photolithography (e.g., various wavelengths including G line, I line, 248 nm, 193 nm, 157 nm and 13.2-13.4 nm), contact lithography, e-beam lithography, x-ray lithography, ion-beam lithography, atomic lithography, and the like.

[0024] Currently, within the art, treatment of template 18 with surfactant molecules is provided as a diluted spray-on surfactant/solvent solution. In using the diluted spray-on surfactant/solvent solution, it is generally difficult to obtain precise distribution of the surfactant molecules on the templates.

[0025] FIGS. 3A-3C illustrate simplified side views of an exemplary embodiment for providing precise distribution of a surfactant on template 18 to provide two regions: a surfactant rich region SRR and a surfactant depleted region SDR. Generally, treatment of template 18, by contacting template 18 with surfactant (e.g., surfactant liquid 60) deposited on substrate 12, may provide control over distribution of surfactant liquid 60 to provide surfactant rich region SRR and surfactant depleted region SDR. Control of the distribution may further allow for control over the magnitude of the contact angle Θ_{SRR} within the surfactant rich region SRR and the magnitude of the contact angle Θ_{SDR} within the surfactant depleted region SDR. As such, the contact angle Θ_{SRR} within the surfactant rich region SRR and the contact angle Θ_{SDR} within the surfactant depleted region SDR may target different applications providing for $\Theta_{SRR} > \Theta_{SDR}$; $\Theta_{SRR} < \Theta_{SDR}$; and/or $\Theta_{SRR} \approx \Theta_{SDR}$. Additionally, by varying the composition of surfactant liquid 60, contact angles Θ_{SRR} and/or Θ_{SDR} may be controlled to target different applications providing for $\Theta_{SRR} > \Theta_{SDR}$; $\Theta_{SRR} < \Theta_{SDR}$; and/or $\Theta_{SRR} \approx \Theta_{SDR}$.

[0026] Referring to FIG. 3A, surface 62 of template 18 initially may be substantially free of surfactant liquid 60. Alternatively, surface 62 of template 18 may be pre-treated. For example, surface 62 of template 18 may be pre-treated with the diluted spray-on surfactant/solvent solution described above.

[0027] To provide surfactant liquid 60 to template 18, imprint fluid 58 may be deposited on substrate 12. Imprint fluid 58 may include, but is not limited to, polymerizable material 34 and surfactant liquid 60. Polymerizable material 34 may be formed from several different families of bulk materials. For example, polymerizable material 34 may be fabricated from bulk materials including, but not limited to, vinyl ethers, methacrylates, epoxies, thiol-enes and acrylates, and/or the like. Bulk materials are described in further detail in U.S. Patent No. 7,307,118, which is hereby incorporated by reference herein.

[0028] Once imprint fluid 58 is deposited on substrate 12, generally the surfactant liquid 60 may migrate to the gas/liquid interface. As such, by positioning template 18 in contact with imprint fluid 58 as shown in FIG. 3B, at least a portion of surface 62 of template 18 may be treated with surfactant liquid 60.

[0029] Generally, after treatment with surfactant liquid 60, surface 62 of template 18 may be defined by the surfactant rich region SRR and/or the surfactant depleted region SDR as illustrated in FIG. 3C. The surfactant rich region SRR may include a layer of surfactant liquid 60 having a thickness t_3. For example, the layer of surfactant liquid 60 may have a thickness t_3 of approximately 0.2 to 5 nm. The surfactant depleted region SDR may include a layer of surfactant liquid 60 having a thickness t_4. Generally, the thickness t_4 of the surfactant depleted region SDR may be substantially reduced as compared to the thickness t_3 of the surfactant rich region SRR. For example, the thickness t_4 of the surfactant depleted region may be zero or near zero.

[0030] Distribution of surfactant liquid 60 on template 18 may provide the contact angle Θ_{SRR} at the surfactant rich region SRR and the contact angle Θ_{SDR} at the surfactant depleted region SDR to be $\Theta_{SRR} > \Theta_{SDR}$; $\Theta_{SRR} < \Theta_{SDR}$; and/or $\Theta_{SRR} \approx \Theta_{SDR}$. Generally, the contact angle Θ_{SRR} at the surfactant rich region SRR and the contact angle Θ_{SDR} at the surfactant depleted region SDR may be less than approximately 55°.

[0031] Further, the composition of surfactant liquid 60 may provide for different contact angles; surfactant liquid 60 may be selected to provide an approximate contact angle Θ_{SRR} at the surfactant rich regions SRR and an approximate contact angle Θ_{SDR} at the surfactant depleted regions SDR. As such, selection of surfactant liquid 60 may provide $\Theta_{SRR} > \Theta_{SDR}$, $\Theta_{SRR} < \Theta_{SDR}$, and/or $\Theta_{SRR} \approx \Theta_{SDR}$, depending on the design considerations of an application.

[0032] Exemplary surfactant (e.g., surfactant liquids 60) may include surfactant components such as fluoro-aliphatic polymeric esters, fluorosurfactants of polyoxyethlene, fluorosurfactants of polyalkyl ether, fluroalkyl polyethers, and/or the like. Exemplary surfactant components are further described in U.S. Patent No. 3,403,122, U.S. Patent No. 3,787,351, U.S. Patent No. 4,803,145, U.S. Patent No. 4,835,084, U.S. Patent No. 4,845,008, U.S. Patent No. 5,280,644, U.S. Patent No. 5,747,234, U.S. Patent No. 6,664,354, and U.S. Patent Publication No. 2006/0175736, all of which are hereby incorporated by reference herein.

[0033] Exemplary commercially available surfactant components include, but are not limited to, ZONYL® FSO, ZONYL® FSO-100, ZONYL® FSN-100, and ZONYL® FS-300, manufactured by E.I. du Pont de Nemours and Company having an office located in Wilmington, Delaware; FC-4432, FC-4430, and FC-430, manufactured by 3M having an office located in Maplewood, Minnesota; MASURF® FS425, MASURF® FS1700, MASURF® FS2000, MASURF® FS1239, manufactured by Mason Chemical Company having an office located in Arlington Heights, IL; Lodyne S-107B, Lodyne S-220N, manufactured by Ciba-Geigy Corporation having an office located in Basel, Switzerland; Unidyne NS1602, Unidyne NS1603, Unidyne NS1606a, manufactured by Daikin having an office located in Kita-ku, Osaka, Japan; MegaFace R-08 manufactured by Dainippon Ink & Chemical having an office located in Nihonbaski, Chuo, Japan.

[0034] Selection of surfactant (e.g., surfactant liquid 60) may be provided through contact angle analysis. Contact angle analysis may include simulated testing of the contact angles on simulated surfactant rich regions SRR_{SIM} and/or simulated surfactant depleted regions SDR_{SIM}.

[0035] Referring to FIGS. 4A-4C, contact angle analysis on simulated surfactant rich regions SRR_{SIM} may be provided by contact angle measurement by goniometer 70 on testing substrate 72. Testing substrate 72 may be formed of material that is substantially similar to template 18. For example, testing substrate 72 may be formed of fused silica. Additionally, testing substrate 72 may be sized such that it is substantially similar to template 18 and/or sized to accommodate at least one simulated surfactant rich region SRR_{SIM}.

[0036] Testing substrate 72 may be cleaned, baked dry, and stored in a nitrogen box. As illustrated in FIG. 4A, testing substrate 72 may be rinsed with a surfactant solution to provide film 74 having a thickness t_5. The surfactant solution may be a diluted surfactant solution. For example, the surfactant solution may be a solution formed of a percentage of weight of surfactant molecules in Isopropyl Alcohol (IPA). Surfactant molecules within the surfactant solution may be similar to surfactant molecules within surfactant liquid 60. Film 74 of the surfactant solution on testing substrate 72 may be dried, and/or a substantial portion of film 74 may evaporate, reducing thickness t_5 as illustrated in FIG. 4B. For example, after evaporation, thickness t_5 may be substantially zero as IPA within the surfactant solution may be substantially evaporated.

[0037] Referring to FIG. 4C, drops of imprint fluid 58 may be deposited on testing substrate 72 to form the simulated surfactant rich region SRR_{SIM}. Each drop of imprint fluid 58 may have a volume V_D. For example, the volume V_D of each drop may be approximately 5 μL. The volume V_D may include polymerizable material 34 and surfactant liquid 60. Surfactant liquid 60 may be comprised of similar surfactant molecules as compared to surfactant solution 74. Alternatively, surfactant liquid 60 may be comprised of different surfactant molecules as compared to surfactant solution 74.

[0038] The contact angle of imprint fluid 58 on testing substrate 72 may be measured at multiple locations on testing substrate 72. For example, the contact angle of imprint fluid 58 may be measured at several locations (e.g., seven locations) using goniometer 70. The contact angles at multiple locations may be averaged to provide the magnitude of the contact angle $\theta_{R\text{-}SIM}$ on the simulated surfactant rich regions SRR_{SIM}.

[0039] Referring to FIGS. 5A-5C, contact angle analysis on simulated surfactant depleted regions SDR_{SIM} may be provided contact angle measurements of goniometer 70 on testing substrate 72a. Testing substrate 72a may be formed of material that is substantially similar to template 18 and/or material that is substantially similar to testing substrate 72. For example, testing substrate 72a may be formed of fused silica. Additionally, testing substrate 72a may be sized such that it is substantially similar to template 18 and/or sized to accommodate at least one simulated surfactant depleted region SDR_{SIM}.

[0040] Similar to testing substrate 72 in FIG. 4, testing substrate 72a in FIG. 5A may be cleaned, baked dry, and stored in a nitrogen box. Testing substrate 72a may then be rinsed with a solvent (e.g., IPA) to provide film 78 having a thickness t_6. Film 78 of solvent on testing substrate 72a may be dried and/or at least a portion of film 78 of solvent may evaporate reducing thickness t_6 as illustrated in FIG. 5B. For example, thickness t_6 may be substantially zero after evaporation of a substantial portion of IPA.

[0041] Referring to FIG. 5C, drops of imprint fluid 58 may be deposited on testing substrate 72a to form the simulated surfactant depleted region SDR_{SIM}. Each drop of imprint fluid 58 may have a volume V_{D2}. For example, the volume V_{D2} of each drop may be approximately 5 μL. The volume V_{D2} may be substantially similar to the volume V_D of drops on testing substrate 72 in FIG. 4. The volume V_{D2} of drops on testing substrate 72a in FIG. 5C may include polymerizable material 34 and surfactant liquid 60.

[0042] The contact angle of imprint fluid 58 on testing substrate 72a may be measured at multiple locations on testing substrate 72a. For example, the contact angle of imprint fluid 58 may be measured at several locations (e.g., seven locations) by goniometer 70. The contact angles at multiple locations may be averaged to provide the magnitude of the contact angle $\theta_{D\text{-}SIM}$ on the simulated surfactant depleted regions SDR_{SIM}.

[0043] Variations of surfactant liquid 60 within imprint fluid 58 deposited on testing substrate 72a may provide control over the contact angles within the simulated surfactant rich regions SRR_{SIM} and/or the simulated surfactant depleted regions SDR_{SIM} leading to control over the surfactant rich regions SRR and the surfactant depleted regions SDR during imprinting. For example, imprint fluid 58 formed of surfactant liquid 60 having approximately 0.17% FCC4432 and 0.33% FC4430 and polymerizable material 34 may provide for $\theta_{R\text{-}SIM}$ of approximately 20° and $\theta_{D\text{-}SIM}$ of approximately 22° such that $\theta_{R\text{-}SIM} \approx \theta_{D\text{-}SIM}$. In another example, imprint fluid 58 formed of surfactant liquid 60 having approximately 0.5% R-08 and polymerizable material 34 may provide for $\theta_{R\text{-}SIM}$ of approximately 15° and $\theta_{D\text{-}SIM}$ of approximately 22° such that $\theta_{R\text{-}SIM} < \theta_{D\text{-}SIM}$. In another example, imprint fluid 58 formed of surfactant liquid 60 having approximately 0.5% FS200 and polymerizable material 34 may provide for $\theta_{R\text{-}SIM}$ of approximately 18° and $\theta_{D\text{-}SIM}$ of approximately 10° such that $\theta_{R\text{-}SIM} > \theta_{D\text{-}SIM}$.

Controlling contact angle to provide suitable wetting characteristics

[0044] FIG. 6 illustrates a flow chart of exemplary method 300 for providing suitable wetting characteristics between template 18 and polymerizable material 34. Suitable wetting characteristics may be created by controlling the contact angles Θ_{SRR} and Θ_{SDR}. For example, by using results obtained from the contact angle analysis of the simulated surfactant rich region SRR_{SIM} and the simulated surfactant depleted region SDR_{SIM}, surfactant liquid 60 providing approximate the contact angles $\Theta_{R\text{-}SIM}$ and $\Theta_{D\text{-}SIM}$ may be selected such that $\Theta_{SRR} > \Theta_{SDR}$. Application of surfactant liquid 60 on template 18 may then be controlled to provide the surfactant rich region SRR and the surfactant depleted region SDR on template 18. The reduced contact angle Θ_{SDR} in the surfactant depleted region SDR on template 18, as compared to the contact angle Θ_{SRR} in the surfactant rich region SRR, may provide polymerizable material 34 an additional driving force to wet the surfactant depleted region SDR. As such, voids formed within patterned layer 46 (shown in FIG. 2) may be significantly reduced during imprinting.

[0045] In a step 302, multiple surfactant solutions 74 and/or multiple surfactant liquids 60 may be provided. In a step 304, the contact angle $\Theta_{R\text{-}SIM}$ in the simulated surfactant rich regions SRR_{SIM} on testing substrate 72 rinsed with surfactant solution 74 may be determined for each surfactant liquid 60. Alternatively, the contact angle $\Theta_{R\text{-}SIM}$ may be determined by a reference document (e.g., a database) from prior testing using surfactant liquid 60 and surfactant solution 74. In a step 306, the contact angle $\Theta_{D\text{-}SIM}$ in the simulated surfactant depleted region SDR_{SIM} on testing substrate 72a rinsed in solvent 78 may be determined for each surfactant liquid 60. Alternatively, the contact angle $\Theta_{D\text{-}SIM}$ may be determined by a reference document (e.g., database) from prior testing using surfactant liquid 60 and solvent 78. In a step 308, surfactant liquid 60 suitable for imprinting may be determined. For example, surfactant liquid 60 that provides $\Theta_{SRR} > \Theta_{SDR}$ may be selected. In a step 310, imprint material 58 formed of polymerizable material 34 and surfactant liquid 60 may be deposited on substrate 12. It should be noted that surfactant liquid 60 may be applied directly to template 18 and need not be directly added to polymerizable material 34 prior to contact of template 18 with polymerizable material 34. Generally, surfactant liquid 60 in imprint fluid 58 may migrate towards the gas/liquid interface. In a step 312, template 18 may contact imprint fluid 58 providing at least a portion of surfactant liquid 60 on surface 62 of template 18 to form at least one surfactant rich region SRR and at least one surfactant depleted region SDR. The approximate contact angle Θ_{SRR} provided within at least one surfactant rich region SRR during imprinting may be less than, greater than, or substantially similar to the approximate contact angle Θ_{SDR} within at least one surfactant depleted region SDR during imprinting. In a step 314, polymerizable material 34 may be solidified to provide patterned layer 46.

Drop pattern shifting applications using contact angle analysis

[0046] As illustrated in FIGS. 3A-3C, distribution of surfactant on template 18 may provide two regions: the surfactant rich region SRR and the surfactant depleted region SDR. During this stage, the surfactant rich region SRR on template 18 is generally located at the point of contact between template 18 and imprint fluid 58. During filling of the desired volume between mold 20 and substrate 12, as illustrated in FIGS. 7A and 7B, surfactant liquid 60 within imprint fluid 58 may migrate to the gas/liquid interface as template 18 contacts imprint fluid 58 and imprint fluid 58 spreads on surface 44 of substrate 12. As such, surfactant liquid 60 may build up in localized regions on template 18 forming surfactant depleted regions SDR at drop locations 80 and surfactant rich regions SRR between drop locations 80. The surfactant rich regions SRR between drop locations 80 generally form interstitial areas where voids may occur.

[0047] Drop shifting may even out surfactant distribution on template 18. For example, FIG. 7B illustrates surfactant depleted regions SDR and surfactant rich regions SRR after a first drop pattern imprint. In a subsequent imprint, a second drop pattern may be used that provides drop locations 80 at a shifted location as compared to the first drop pattern. The shifted location of drops 80 in the subsequent drop pattern may be positioned such that at least one of drops 80 of imprint fluid 58 contacts template 18 at a surfactant rich region SRR.

[0048] During imprinting of multiple substrates 12, drop shift patterning may be used successively or sporadically. For example, a first drop pattern may be used to imprint followed by one or more drop shifted patterns. Alternatively, a first drop pattern may be used multiple times prior to one or more drop shifted patterns being used. In a similar fashion, a first drop pattern may be used once followed by multiple uses of one or more drop shifted patterns.

[0049] Further, by reducing the contact angle Θ_{SDR} of the surfactant depleted region SDR as compared to the contact angle Θ_{SRR} of the surfactant rich region SRR such that $\Theta_{SRR} > \Theta_{SDR}$, the lower contact angle Θ_{SDR} of the surfactant depleted region SDR may provide additional driving force for polymerizable material 34 to wet and fill the surfactant depleted region SDR.

[0050] FIG. 8 illustrates a flow chart of another exemplary method 400 for providing suitable wetting characteristics between a template and a polymerizable material using drop pattern shifting. In a step 402, multiple surfactant solutions 74 and/or multiple surfactant liquids 60 may be provided. In a step 404, the contact angle $\Theta_{R\text{-}SIM}$ in the simulated surfactant rich regions SRR_{SIM} on testing substrate 72 rinsed with surfactant solution 74 may be determined for each surfactant liquid 60. In a step 406, the contact angle $\Theta_{D\text{-}SIM}$ in the simulated surfactant depleted region SDR_{SIM} on testing substrate 72a rinsed in solvent 78 may be determined for each surfactant liquid 60. In a step 408, surfactant liquid 60 that provides a suitable contact angle may be selected. For example, surfactant liquid 60 that provides contact angles $\Theta_{SRR} > \Theta_{SDR}$ may be selected.

[0051] In a step 410, imprint material 58 formed of polymerizable material 34 and surfactant liquid 60 may be dispensed on substrate 12 in a first pattern. Generally, surfactant liquid 60 in imprint fluid 58 may migrate towards the gas/liquid interface. In a step 412, template 18 may contact imprint fluid 58. In a step 414, imprint fluid 58 may be solidified to provide first patterned layer 46. In a step 416, template 18 may be separated from first patterned layer 46 with template 18 having the surfactant rich regions SRR and the surfactant depleted regions SDR upon removal.

[0052] In a step 418, imprint material 58 formed of polymerizable material 34 and surfactant liquid 60 may be dispensed in a second drop pattern on second substrate 12. The second drop pattern may be substantially similar to the first drop pattern and shifted a position x and/or a position y such that at least one drop location contacts at least one surfactant depleted region SDR of template 18. In a step 420, template 18 may contact imprint fluid 58. In a step 422, imprint fluid 58 may be solidified to provide second patterned layer 46. The second patterned layer 46 may have limited or no voids.

WHAT IS CLAIMED IS:

1. A method for determining wetting characteristics between a template and a polymerizable material, the method comprising:

dispensing on a substrate a first imprint fluid comprising a first polymerizable material and a surfactant;

contacting the template, in superimposition with the substrate, to the first imprint fluid such that at least a portion of the surfactant of the first imprint fluid contacts the template;

separating the template and the first imprint fluid to form on a surface of the template a surfactant rich region having a first thickness and a surfactant depleted region having a second thickness;

contacting the template with a second imprint fluid such that at least a portion of a second polymerizable material contacts the template, wherein a first contact angle between the template and the second polymerizable material within surfactant rich region is not equal to a second contact angle between the template and the second polymerizable material within the surfactant depleted region.

2. The method of claim 1, wherein the first contact angle within the surfactant rich region is greater than the second contact angle within the surfactant depleted region.

3. The method of claim 1, wherein the first contact angle within the surfactant rich region is less than the second contact angle within the surfactant depleted region.

4. The method of claim 1, wherein the first thickness is greater than the second thickness.

5. The method of claim 1, wherein the second thickness is substantially zero.

6. The method of claim 1, wherein a magnitude of the first contact angle is less than 50 degrees.

7. The method of claim 1, further comprising solidifying the second imprint fluid after the second imprint fluid is contacted with the template.

8. The method of claim 1, wherein the template is an imprint lithography template.

9. A method comprising:

determining, for first and second surfactant liquids, a first contact angle within a simulated surfactant rich region on a first substrate, the first and second surfactant liquids having different physical properties;

determining, for each of the first and second surfactant liquids, a second contact angle within a simulated surfactant depleted region on a second substrate;

selecting one of the first and second surfactant liquids provided for use during imprinting as a function of the first and second contact angles.

10. The method of claim 9, wherein determining the first contact angle within the simulated surfactant rich region comprises:

rinsing the first substrate with a surfactant solution;

dispensing an imprint fluid on the first substrate to form the simulated surfactant rich region, the imprint fluid being formed of a polymerizable material and a third surfactant liquid; and,

measuring the first contact angle within the simulated surfactant rich region.

11. The method of claim 10, comprising measuring the first contact angle with a goniometer.

12. The method of claim 9, wherein determining the measured contact angle within the simulated surfactant depleted region comprises:

rinsing the second testing substrate with a solvent;

dispensing an imprint fluid on the second testing substrate to form the simulated surfactant depleted region, the imprint fluid being formed of polymerizable material and the surfactant liquid; and,

measuring contact angle of the simulated surfactant depleted region.

13. The method of claim 12, wherein the second contact angle is measured by a goniometer.

14. The method of claim 9, wherein the first contact angle within the simulated surfactant rich region is greater than the second contact angle within the simulated surfactant depleted region for the selected one of the first and second surfactant liquids.

15. The method of claim 9, wherein the first contact angle within the simulated surfactant rich region is less than the second contact angle within the simulated surfactant depleted region for the selected one of the first and second surfactant liquids.

16. The method of claim 9, wherein the first contact angle within the simulated surfactant rich region is substantially similar to the second contact angle within the simulated surfactant depleted region for the selected or one of the first and second surfactant liquids.

17. The method of claim 9, further comprising:

positioning a template in superimposition with a third substrate; and

dispensing a first imprint fluid formed of a first polymerizable material and the selected one of the first and second surfactant liquids on a surface of the third substrate.

18. The method of claim 17, further comprising:

contacting the template with the first imprint fluid such that at least a portion of the selected one of the first and second surfactant liquids contacts the template to form at least one surfactant rich region and at least one surfactant depleted region on a surface of the template.

19. The method of claim 18, further comprising:

dispensing a second imprint fluid on a fourth substrate in a first drop pattern;

contacting the template with the second imprint fluid on the fourth substrate;

solidifying the second imprint fluid to form a patterned layer; and

separating the patterned layer from the template.

20. The method of claim 19, further comprising:

dispensing a third imprint fluid on a fifth substrate in a second drop pattern, the second drop pattern providing a drop shifted pattern of the first drop pattern and determined to provide substantially even distribution of the selected one of the first and second surfactant liquids on the template during contact with the fifth substrate; and

contacting the template with the third imprint fluid deposited on the fifth substrate.

21. A method for determining wetting characteristics between a template and a polymerizable material, the method comprising:

dispensing a first drop pattern of a first imprint fluid on a first substrate, the first substrate in superimposition with a template;

contacting the template with the first drop pattern of the first imprint fluid to imprint and provide a first patterned layer;

separating the template from the first patterned layer, wherein a surface of the template includes at least one surfactant rich region and at least one surfactant depleted region;

dispensing a second drop pattern of a second imprint fluid on a second substrate, the second drop pattern determined to provide at least one drop of the second imprint fluid in the surfactant rich region of the template during contact of the template with the second drop pattern of the second imprint fluid; and,

contacting the template with the second drop pattern of the second imprint fluid to imprint and provide a second patterned layer.

22. The method of claim 21, wherein a first contact angle between the template and the second imprint fluid in the surfactant rich region is less than a second contact angle between the template and the second imprint fluid in the surfactant depleted region.

23. The method of claim 21, wherein a first contact angle between the template and the second imprint fluid in the surfactant rich region is greater than a second contact angle between the template and the second imprint fluid in the surfactant depleted region.

24. The method of claim 21, wherein the template is an imprint lithography template.

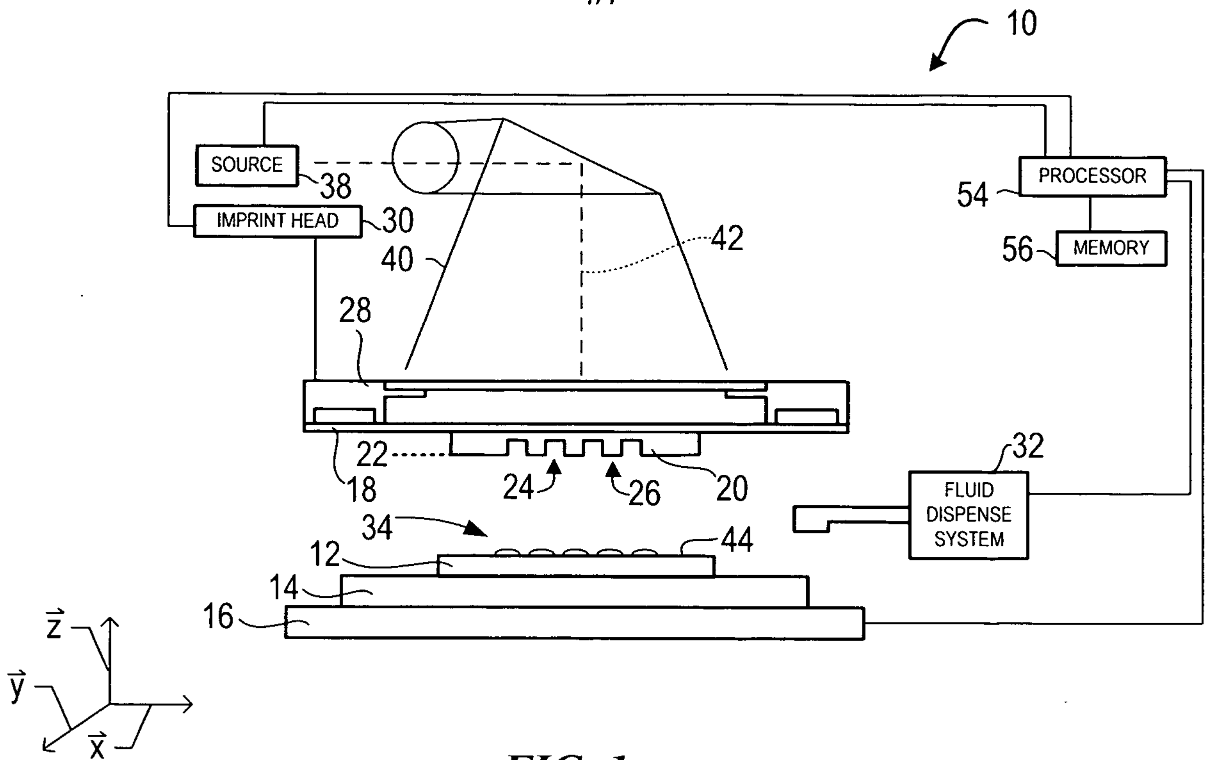
10
SOURCE
38
IMPRINT HEAD
30
PROCESSOR
54
MEMORY
56
42
40
28
22
18
24
26
20
32
FLUID
DISPENSE
SYSTEM
34
44
12
14
16
z
y
x

FIG. 1

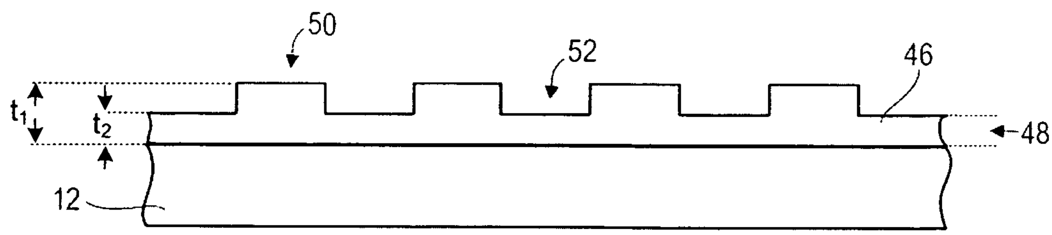
50
52
46
t1
t2
48
12

FIG. 2

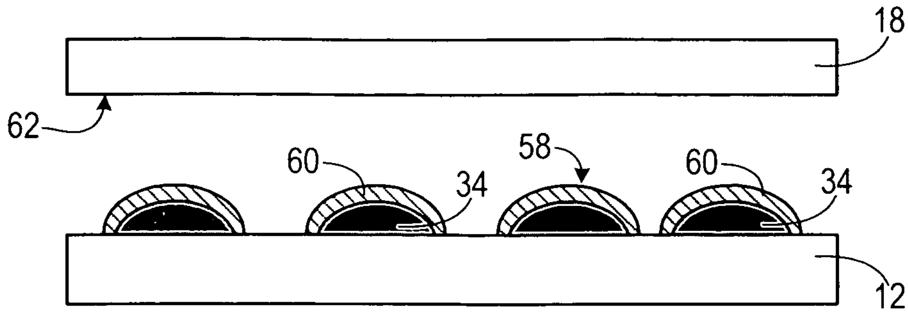

FIG. 3A

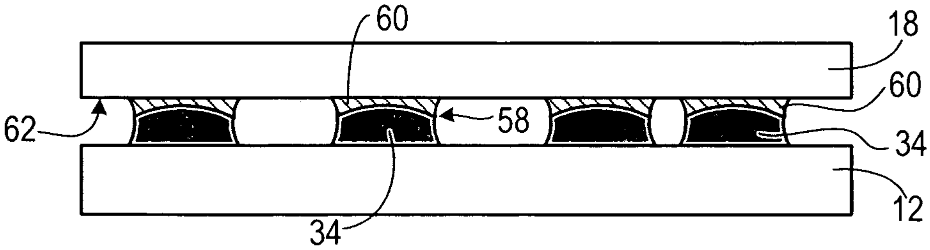

FIG. 3B

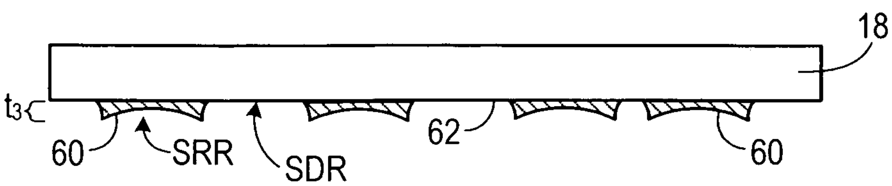

FIG. 3C

FIG. 4A

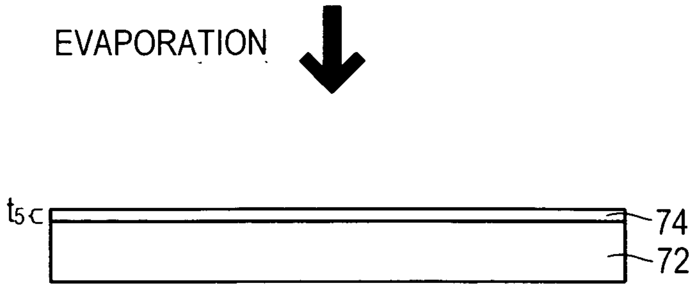

FIG. 4B

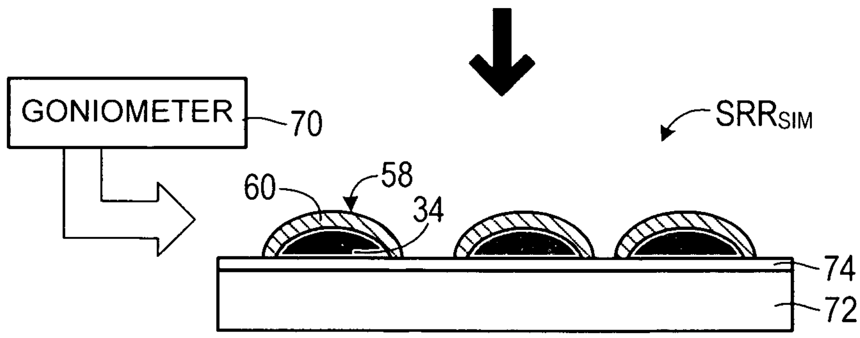

FIG. 4C

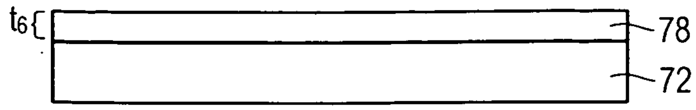

FIG. 5A

EVAPORATION

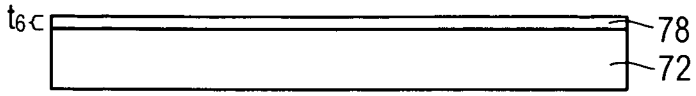

FIG. 5B

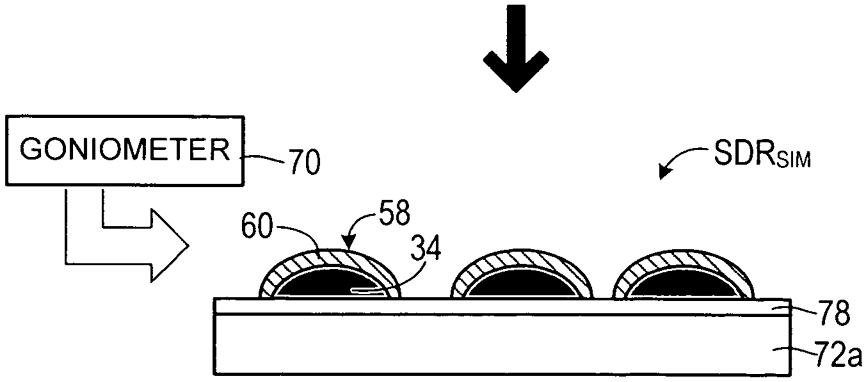

FIG. 5C

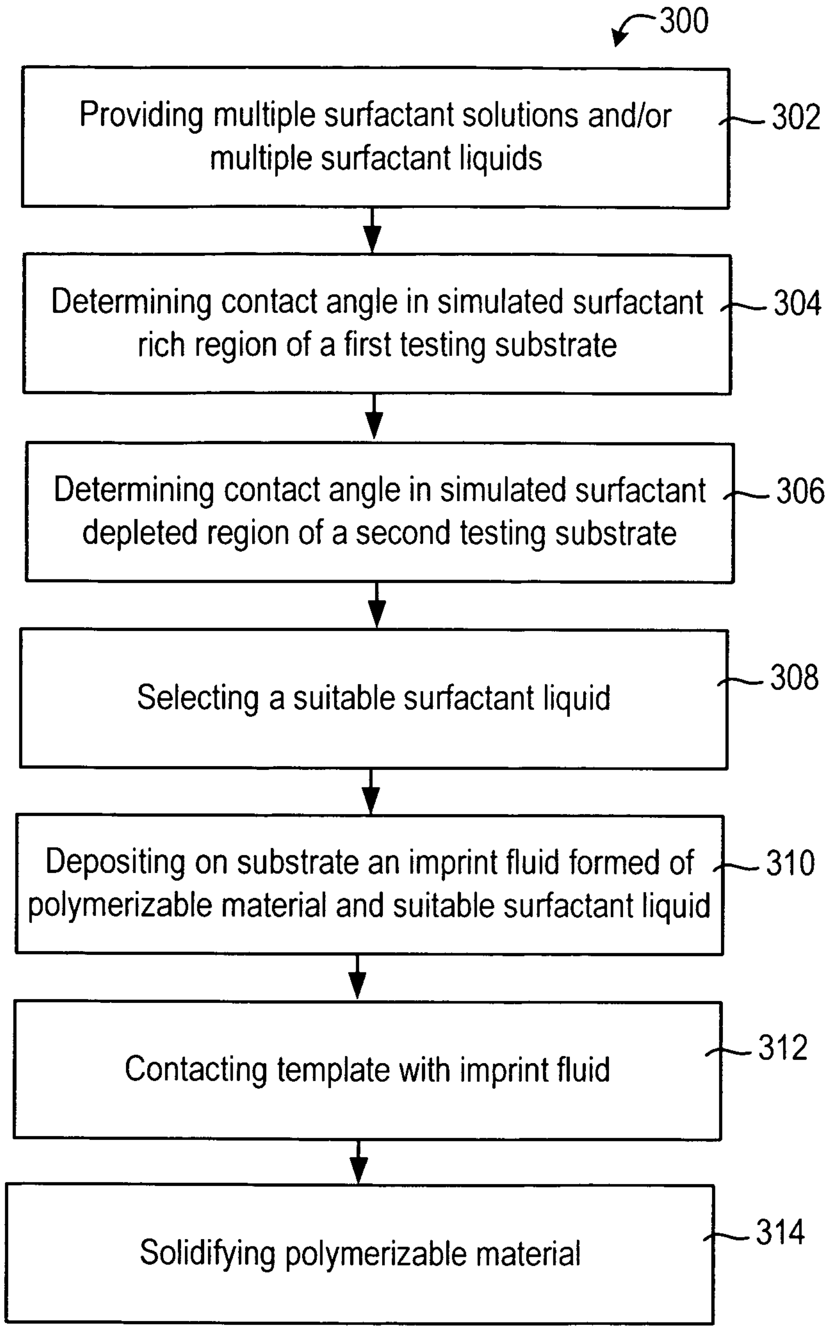
300
Providing multiple surfactant solutions and/or multiple surfactant liquids
302
Determining contact angle in simulated surfactant rich region of a first testing substrate
304
Determining contact angle in simulated surfactant depleted region of a second testing substrate
306
Selecting a suitable surfactant liquid
308
Depositing on substrate an imprint fluid formed of polymerizable material and suitable surfactant liquid
310
Contacting template with imprint fluid
312
Solidifying polymerizable material
314

FIG. 6

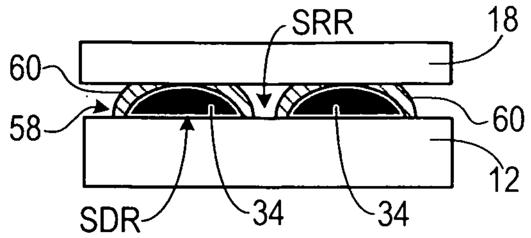

FIG. 7A

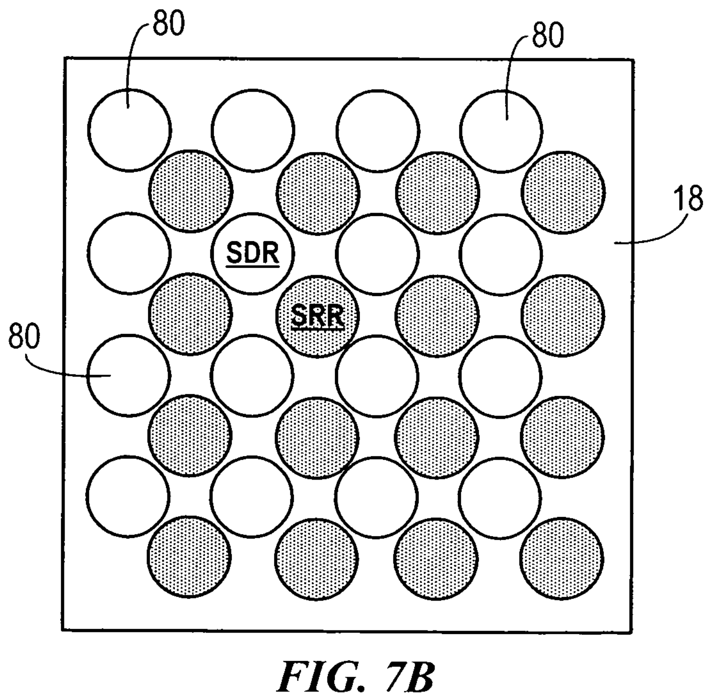

FIG. 7B

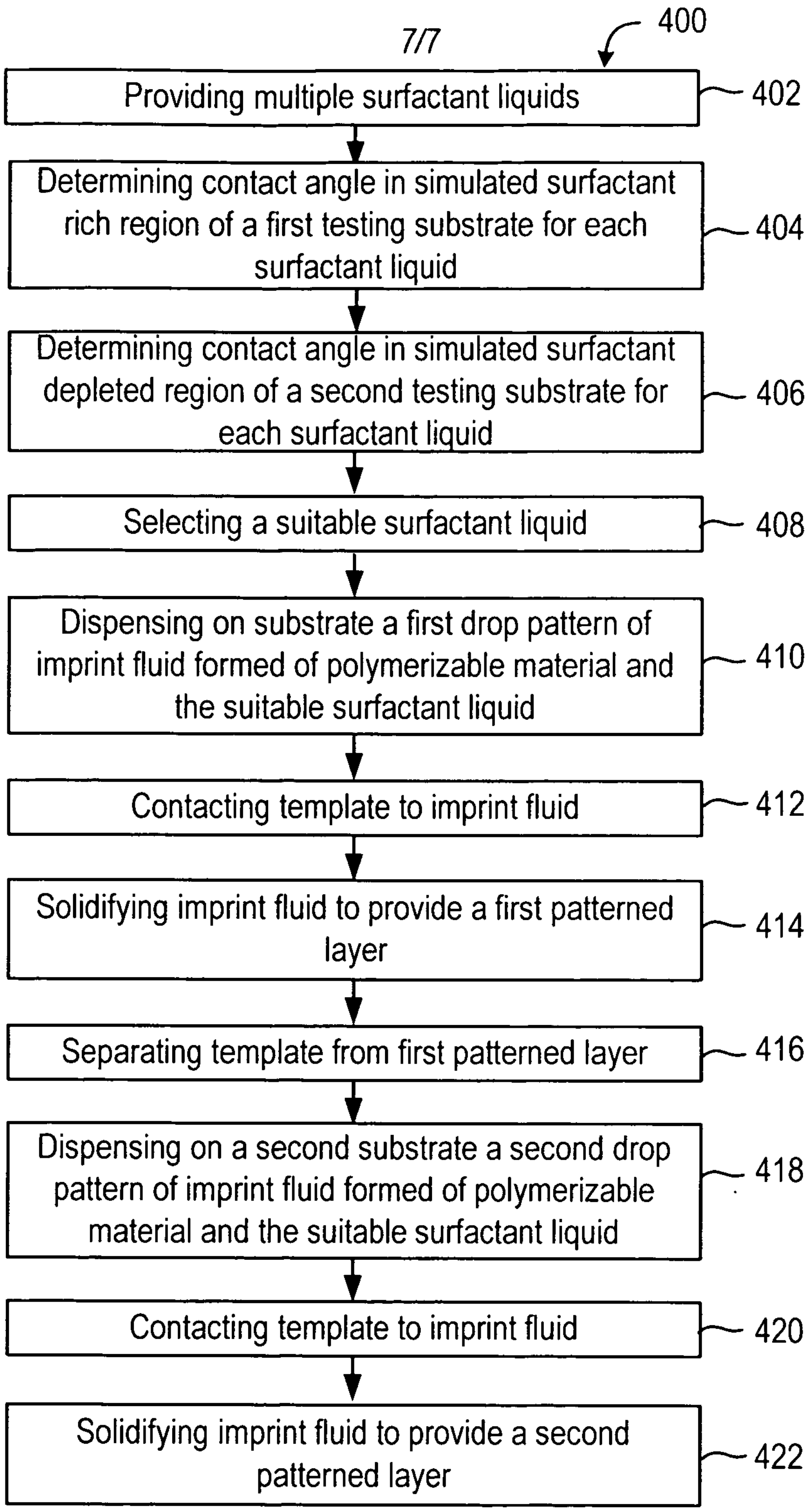
400
Providing multiple surfactant liquids
402
Determining contact angle in simulated surfactant rich region of a first testing substrate for each surfactant liquid
404
Determining contact angle in simulated surfactant depleted region of a second testing substrate for each surfactant liquid
406
Selecting a suitable surfactant liquid
408
Dispensing on substrate a first drop pattern of imprint fluid formed of polymerizable material and the suitable surfactant liquid
410
Contacting template to imprint fluid
412
Solidifying imprint fluid to provide a first patterned layer
414
Separating template from first patterned layer
416
Dispensing on a second substrate a second drop pattern of imprint fluid formed of polymerizable material and the suitable surfactant liquid
418
Contacting template to imprint fluid
420
Solidifying imprint fluid to provide a second patterned layer
422

FIG. 8