

METHOD TO MODIFY AN OPTICAL DEVICE RESIST

BACKGROUND

Field

[0001] Embodiments of the present disclosure generally relate to optical devices for augmented, virtual, and mixed reality. More specifically, embodiments described herein provide for methods of optical device fabrication.

Description of the Related Art

[0002] Virtual reality is generally considered to be a computer generated simulated environment in which a user has an apparent physical presence. A virtual reality experience can be generated in 3D and viewed with a head-mounted display (HMD), such as glasses or other wearable display devices that have near-eye display panels as lenses to display a virtual reality environment that replaces an actual environment.

[0003] Augmented reality, however, enables an experience in which a user can still see through the display lenses of the glasses or other HMD device to view the surrounding environment, yet also see images of virtual objects that are generated for display and appear as part of the environment. Augmented reality can include any type of input, such as audio and haptic inputs, as well as virtual images, graphics, and video that enhances or augments the environment that the user experiences. As an emerging technology, there are many challenges and design constraints with augmented reality. Conventional fabrication methods require the use of a lithography process. Unfortunately, the lithography process may not produce the desired results.

[0004] Accordingly, what is needed in the art is methods of manufacturing optical devices.

SUMMARY

[0005] In one aspect a method of optical device fabrication is described. The method includes identifying a graytone mask profile of a mask substrate. A graytone mask pattern of the mask substrate is generated, in which mask structures are disposed on a surface of the mask substrate that correspond to the graytone mask pattern. An optical device resist is exposed by projecting a light through the graytone mask pattern that is disposed over an optical device substrate. The optical device resist has a

varying thickness according to the graytone mask pattern after developing the optical device resist.

[0006] In another aspect a method of optical device fabrication is described. The method includes identifying a graytone mask profile of a mask substrate. A graytone mask pattern of the mask substrate is generated, in which print structures are disposed on a diffuser coupled to a surface of the mask substrate that correspond to the graytone mask pattern. An optical device resist is exposed by projecting a light through the graytone mask pattern that is disposed over an optical device substrate. The optical device resist has a varying thickness according to the graytone mask pattern after developing the optical device resist.

[0007] In another aspect a method of optical device fabrication is described. The method includes identifying a graytone mask profile of a mask substrate. A graytone mask pattern of the substrate is generated, in which mask structures are disposed on a dose adjustment layer coupled to a diffuser and a surface of the mask substrate that correspond to the graytone mask pattern. An optical device resist is exposed by projecting a light through the graytone mask pattern that is disposed over an optical device substrate. The optical device resist has a varying thickness according to the graytone mask pattern after developing the optical device resist.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] So that the manner in which the above recited features of the present disclosure can be understood in detail, a more particular description of the disclosure, briefly summarized above, may be had by reference to embodiments, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only exemplary embodiments and are therefore not to be considered limiting of its scope, and may admit to other equally effective embodiments.

[0009] Figure 1 is a perspective, frontal view of an optical device according to embodiments described herein.

[0010] Figure 2 is a schematic, cross-sectional view of an optical device according to embodiments.

[0011] Figure 3 is a flow diagram of a method to compensate optical device resist non-uniformities according to embodiments.

[0012] Figures 4A – 4E are illustrative schematics of a graytone mask pattern according to embodiments.

[0013] Figure 5 is an illustrative schematic of print structure on a diffuser according to embodiments.

[0014] To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures. It is contemplated that elements and features of one embodiment may be beneficially incorporated in other embodiments without further recitation.

DETAILED DESCRIPTION

[0015] Embodiments of the present disclosure generally relate to optical devices for augmented, virtual, and mixed reality. More specifically, embodiments described herein provide for methods and systems for adjusting graytone mask patterns to compensate for non-uniformities in optical device resists.

[0016] Embodiments of the present disclosure may reduce non-uniformities of optical device resists by identifying a graytone mask profile and producing a mask structure or print structure to offset or reduce the non-uniformities of optical device resists. Producing the mask structures and/or print structures would be lower cost and have a fast turn-a-round for rapid changes in an optical device resist. Moreover, embodiments of the present disclosure can correct for a plurality of individual mask, diffuser, or mask substrate differences quickly, and without the need for process or handling modifications.

[0017] Figure 1 is a perspective, frontal view of an optical device 100. It is to be understood that the optical devices 100 described herein are exemplary optical devices and the other optical devices may be used with or modified to accomplish aspects of the present disclosure. The optical device 100 includes a plurality of optical device structures 102 disposed on a surface 103 of an optical device substrate 101. The optical device structures 102 may be nanostructures having sub-micron dimensions, e.g., nano-sized dimensions. Regions of the optical device structures

102 correspond to one or more gratings 104, such as a first grating 104a, a second grating 104b, and a third grating 104c. In one embodiment, which can be combined with other embodiments described herein, the optical device 100 includes at least the first grating 104a corresponding to an input coupling grating and the third grating 104c corresponding to an output coupling grating. In another embodiment, which can be combined with other embodiments described herein, the optical device 100 also includes the second grating 104b corresponding to an intermediate grating. The optical device structures 102 may be angled or binary. The optical device structures 102 may have other cross-sections including, but not limited to, circular, triangular, elliptical, regular polygonal, irregular polygonal, and/or irregular shaped cross-sections.

[0018] In operation, the first grating 104a receives incident beams of light having an intensity from a light engine. In one embodiment, which can be combined with other embodiments described herein, the light engine is a micro display. The incident beams are split by the optical device structures 102 into T1 beams that have all of the intensity of the incident beams in order to direct a virtual image to the intermediate grating (if utilized) or to the third grating 104c. In one embodiment, which can be combined with other embodiments described herein, the T1 beams undergo total-internal-reflection (TIR) through the optical device 100 until the T1 beams come in contact with the optical device structures 102 of the intermediate grating. The optical device structures 102 of the intermediate grating diffract the T1 beams to T-1 beams that undergo TIR through the optical device 100 to the optical device structures 102 of the third grating 104c. The optical device structures 102 of the third grating 104c outcouple the T-1 beams to the user's eye. The T-1 beams outcoupled to the user's eye display the virtual image produced from the light engine from the user's perspective and further increase the viewing angle from which the user can view the virtual image. In another embodiment, which can be combined with other embodiments described herein, the T1 beams undergo total-internal-reflection (TIR) through the optical device 100 until the T1 beams come in contact with the optical device structures 102 of the third grating 104c and are outcoupled to display the virtual image produced from the light engine.

[0019] In embodiments described herein, the thickness-modulated gratings may be created using graytone lithography, also known as grayscale lithography. Grayscale

lithography is a process used to create three-dimensional microstructures in a photoresist layer using an optical graytone (or grayscale) mask. Grayscale masks let varying amounts of light pass through to create thickness-modulated gratings. Using grayscale lithography to create thickness-modulated gratings allows for fewer processing operations and flexible grating design.

[0020] Figure 2 is a schematic, cross-sectional view of an optical device 200. The optical devices 200 are formed in an optical device substrate 101. The optical devices 200 include a plurality of optical device structures 201. The plurality of optical device structures 201 are formed in an area of the optical device substrate 101. The optical device area is an area of the optical device substrate 101 where the optical devices are formed. The optical devices 200 may be formed into the optical device substrate 101 following the method 300. In one embodiment, which can be combined with other embodiments described herein, the optical devices 200 may be formed in a device material (not shown) disposed over a top surface 202 of the optical device substrate 101. The optical devices 200 each have a target thickness distribution 203. The target thickness distribution 203 may be any linear or nonlinear distribution. The target thickness distribution 203 may be the same at each of the optical device areas. The target thickness distribution 203 may be different at each of the optical device areas. The plurality of optical device structures 201 are formed in the optical device substrate 101 according to the target thickness distribution 203.

[0021] As shown in the optical device lens of Figure 2, the plurality of optical device structures 201 are formed in a base substrate 204 of the optical device substrate 101. The plurality of optical device structures 201 may be nanostructures having sub-micron dimensions, e.g., nano-sized dimensions.

[0022] In one embodiment, which can be combined with other embodiments described herein, the optical devices 200 are waveguide combiners, such as augmented reality waveguide combiners. In another embodiment, which can be combined with other embodiments described herein, the optical devices 200 are flat optical devices, such as metasurfaces. The plurality of optical device structures 201 may correspond to an input coupling grating or an output coupling grating of the optical devices 200. The optical devices 200 are not limited to the number of the plurality of optical device structures 201 shown in Figure 2. Although the plurality of optical device

structures 201 shown in Figure 1 are angled relative to a bottom surface 205 of the optical device substrate 101, the plurality of optical device structures 201 may be perpendicular relative to the bottom surface 205 of the optical device substrate 101.

[0023] Now referring to FIG. 3, a graytone mask profile 404 is identified 301. A graytone mask profile 404 may be identified according to a mask substrate 403. A graytone mask profile 404 may include a profile or signature of the mask substrate 403. For example, the graytone mask profile 404 may denote a transmission uniformity of the mask substrate 403. As a further non-limiting example, the graytone mask profile 404 may denote a metrology metric. As a further non-limiting example, the graytone mask profile 404 may denote a signature of track and process. As a further non-limiting example, the graytone mask profile 404 may denote a signature of an etch process. In an embodiment, the graytone mask profile 404 may denote a non-uniformity that exists in the mask substrate 403. A non-uniformity may include one or more bumps, raises, divots, crevices, or the like that lead to a non-uniform layer of the optical device resist.

[0024] At operation 302, a graytone mask pattern 405 is generated from the graytone mask profile 404. The graytone mask pattern 405 may include one or more mask structures 406. The mask structures 406 may be disposed on a bottom surface of the mask substrate 403. The mask substrate 403 may be disposed on a top surface of the mask substrate 403. In some embodiments, the mask substrate 403 includes an intensity map, in which the mask structure substantially offsets a non-uniformity mask substrate. The intensity map may include a variation in optical transmission corresponding to the graytone mask profile 404. For example, the mask substrate 403 may include an intensity map such that a non-uniformity is reduced on the optical device resist, mask substrate, or the like. The mask structures 406 may comprise a critical dimension. A critical dimension is a width of the mask structure. In one embodiment, a large critical dimension may allow more UV light to pass through the graytone mask pattern, whereas a small critical dimension may allow less UV light to pass through the graytone mask pattern. In one embodiment, the mask structures are an absorption material. The mask structures 406 may comprise a pitch. A pitch is a distance between a first edge of a first mask structure and a first edge of a second mask structure. An absorption material is a material capable of absorbing light, e.g., photons. In one embodiment, the mask structures are a reflective material. A reflective

material is a material capable of reflecting light. For example, a reflective material may include chromium or other transition metal having a high specular reflection.

[0025] In an embodiment, the graytone mask pattern 405 includes a resist thickness profile. The resist thickness profile may denote a pattern or profile of the mask substrate 403, diffuser 402, or dose adjustment layer 412 having a resist thickness variation. In an embodiment, the graytone mask pattern 405 may be patterned based on a certain pattern density of the graytone mask profile 404. For example, the graytone mask pattern may be generated to compensate and/or adjust one or more pattern density variations in the mask substrate 403, the diffuser 402, the dose adjusting layer 412, or the like. In an embodiment, the graytone mask pattern 405 may be generated by a design target or previous optical device profile, where a previous optical device profile is a previously exposed optical device, in which pattern density variations were detected to be compensated for. A design target is an ideal optical device resist and/or preferred optical device resist that is desired.

[0026] At operation 303, an optical device resist is exposed. An optical device resist may be exposed in through a hardmask. In one embodiment, a surface of the graytone mask pattern 405 is graded. The shape of the graytone mask pattern 405 of the optical device resist 408 may determine the variable thickness of the thickness of the device structures across the substrate, as shown in Figure 2. In some embodiments, a hardmask 409 may be disposed over the optical device substrate and under the optical device resist 408. The hardmask 409 may be patterned to expose segments of the optical device substrate 101. For example, the hardmask 409 may be patterned by disposing an organic planarization layer (OPL) over a layer of hardmask material on the optical device substrate 101, disposing a photoresist over the OPL, exposing the photoresist to expose portion of the OPL, removing the exposed portions of the OPL to expose portions of the layer of hardmask material, and removing exposed portions of the layer of hardmask material to define a hardmask pattern that corresponds to exposed segments of the substrate. The exposed segments of the optical device substrate 101 to be etched correspond to the critical dimension between the mask structures (as shown in Figure 4A).

[0027] In some embodiments, a resist segment of the optical device resist 408, is etched via a resist etch process, which is selective to the resist material, to expose a

device segment, the device segment may include exposed portions of the hardmask and exposed portions of the substrate. The exposed device segment may be etched via a substrate etch process. In one embodiment, the substrate etch process is an etch process, selective to the substrate which preserves the exposed portions of the hardmask 409 and removes optical device substrate 101 from the exposed portions of the optical device substrate layer of the device segment. The substrate etch process may be repeated for subsequent resist segments and subsequent exposed substrate segments, corresponding to the graytone mask pattern 405. In some embodiments, which can be combined with other embodiments described herein, each of the optical device resist segments to be etched via the resist etch process is exposed by a first proximity mask, and each of the device segments to be etched via the substrate etch process is exposed by a second proximity mask.

[0028] Performing the cyclic etch process may etch the exposed segments of the substrate to form a plurality of device structures. The graytone mask pattern 405 may create the variable thickness of the device structures across the substrate after developing the optical device resist. For example, the thickness of the device structures decreases in the X-direction across the substrate. In one embodiment, which can be combined with other embodiments described herein, the thickness of the device structures is less than a thickness of the substrate. In another embodiment, which can be combined with other embodiments described herein, the thickness of the device structures is substantially equal to a thickness of the grating material layer across a first portion of the substrate, and the thickness of the device structures is less than the thickness of the grating material layer across a second portion of the substrate. In an embodiment, residual resist material of the optical device resist 408 disposed on the hardmask 409 is removed.

[0029] Now referring to FIG. 4A, a diffuser may be added to the top of the graytone mask. UV light 401 may pass through a diffuser 402 prior to entering a mask substrate 403 of a graytone mask. The UV light 401 may be scattered and/or refracted in the diffuser 402 such that incident light is distributed throughout the diffuser 402. The UV light 401 enters a mask substrate 403 of the graytone mask. The mask substrate 403 may be any suitable substrate of a graytone mask. For example, the mask substrate 403 may include glass, quartz, crystal, silicon dioxide, silica, fiberglass, or the like. A first graytone mask pattern may be disposed beneath the graytone mask and formed

via a plurality of mask structures 406, which may be disposed on a surface, *e.g.*, a top surface of the mask substrate 403 or a bottom surface of the mask substrate 403, such that the light is reflected or absorbed upon exiting the mask substrate 403 where a mask structure 406 is disposed. For example, a mask structure 406 of chromium may reflect the UV light 401 from the mask structure 406 towards a mask substrate location where no mask structure 406 reflects, absorbs, or blocks the UV light 401 from exiting the mask substrate 403.

[0030] In some embodiments, the mask structures 406 may be modified to adjust a gap 407 between the mask structures 406. The gap 407 is a gap or distance between a first mask structure edge and a second mask structure edge. The gap 407 may be adjusted by varying the critical dimension or pitch of the mask structures 406. The gap 407 may adjust one or more intensities of UV light that extend towards an optical device resist 408. UV light 401 that exits the mask substrate 403 where no mask structure exists may proceed towards an optical device resist 408 disposed on the optical device substrate 101. The optical device resist 408 may then be exposed according to the graytone mask pattern 405 via the UV light 401 that interacts with the optical device resist 408. A hardmask 409 may be disposed underneath the optical device resist. The hardmask may be patterned to expose segments of the optical device substrate 101.

[0031] Now referring to FIG. 4B, UV light 401 may pass through a second graytone mask pattern 410 having print structures 411 disposed on a top surface of the diffuser 402. The print structures 411 may be composed of any mask structure 406, described above. The print structures 411 may be disposed on the top surface via a printing method, *e.g.*, inkjet printing. For example, the print structure 411 may be printed on the diffuser 402 such that the UV light 401 first interacts with the print structure 411 of the second graytone mask pattern 410 prior to entering the diffuser 402. In an embodiment, the print structure 411 is printed continuously, or in segments. In an embodiment, the second graytone mask pattern 410 having the print structure 411 may be printed to reduce a transmission rate of UV light 401 to the diffuser 402. In an embodiment, the second graytone mask pattern 410 having the print structure 411 may be printed to eliminate transmission rate of UV light 401 to the diffuser 402. In an embodiment, the second graytone mask pattern 410 having the print structure 411

may be printed according to the graytone mask profile 404 to correct for non-uniformities in the mask substrate 403 of the graytone mask.

[0032] Now referring to FIG. 4C, UV light 401 may pass through a second graytone mask pattern 410 having print structures 411 disposed on a bottom surface of the diffuser 402. The print structures 411 may be composed of any mask structure 406, described above. The print structures 411 may be disposed on the bottom surface via a printing method, e.g., inkjet printing. For example, the print structure 411 may be printed on the diffuser 402 such that the UV light 401 first interacts with the diffuser 402 prior to entering the print structure 411 of the second graytone mask pattern 410. In an embodiment, the print structure 411 is printed continuously, or in segments. In an embodiment, the second graytone mask pattern 410 having the print structure 411 may be printed to reduce a transmission rate of UV light 401 to the diffuser 402. In an embodiment, the second graytone mask pattern 410 having the print structure 411 may be printed to eliminate transmission rate of UV light 401 to the diffuser 402. In an embodiment, the second graytone mask pattern 410 having the print structure 411 may be printed according to the graytone mask profile 404 to correct for non-uniformities in the mask substrate 403 of the graytone mask.

[0033] Now referring to FIG. 4D, UV light 401 may pass through a third graytone mask pattern 413 having print structures 411 disposed on a top surface of a dose adjustment layer 412, in which the dose adjustment layer 412 is disposed beneath the diffuser 402. The dose adjustment layer 412 is a transparent substrate capable of transmitting one or more photons or light through the material towards the optical device substrate 101. For example, the dose adjustment layer 412 may include glass, quartz, crystal, silicon dioxide, silica, fiberglass, or the like. The print structures 411 may be composed of any mask structure 406, described above. The print structures 411 may be disposed on the top surface via a printing method, e.g., inkjet printing. For example, the print structure 411 may be printed on the dose adjustment layer 412 such that the UV light 401 first interacts with the print structure 411 of the third graytone mask pattern 413 prior to entering the dose adjustment layer 412. In an embodiment, the print structure 411 is printed continuously, or in segments. In an embodiment, the third graytone mask pattern 413 having the print structure 411 may be printed to reduce a transmission rate of UV light 401 to the dose adjustment layer 412. In an embodiment, the third graytone mask pattern 413 having the print structure

411 may be printed to eliminate transmission rate of UV light 401 to the dose adjustment layer 412. In an embodiment, the third graytone mask pattern 413 having the print structure 411 may be printed according to the graytone mask profile 404 to correct for non-uniformities in the mask substrate 403 of the graytone mask.

[0034] Now referring to FIG. 4E, UV light 401 may pass through a third graytone mask pattern 413 having print structures 411 disposed on a bottom surface of a dose adjustment layer 412, in which the dose adjustment layer 412 is disposed beneath the diffuser 402. The print structures 411 may be composed of any mask structure 406, described above. The print structures 411 may be disposed on the bottom surface via a printing method, *e.g.*, inkjet printing. For example, the print structure 411 may be printed on the dose adjustment layer 412 such that the UV light 401 first interacts with the dose adjustment layer 412 prior to entering the print structure 411 of the third graytone mask pattern 413. In an embodiment, the print structure 411 is printed continuously, or in segments. In an embodiment, the third graytone mask pattern 413 having the print structure 411 may be printed to reduce a transmission rate of UV light 401 to the dose adjustment layer 412. In an embodiment, the third graytone mask pattern 413 having the print structure 411 may be printed to eliminate transmission rate of UV light 401 to the dose adjustment layer 412. In an embodiment, the third graytone mask pattern 413 having the print structure 411 may be printed according to the graytone mask profile 404 to correct for non-uniformities in the mask substrate 403 of the graytone mask.

[0035] Now referring to FIG. 5, a print structure 411 may be printed using a printer head 501. The printer head 501 may include an inkjet printer head capable of depositing a print structure 411 on the diffuser 402. For example, the inkjet printer head may be capable of inkjet printing a chromium deposit having a thickness variation to offset a non-uniformity of the mask substrate.

[0036] While the foregoing is directed to embodiments of the present disclosure, other and further embodiments of the disclosure may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

What is claimed is:

1. A method of optical device fabrication, comprising:
 - identifying a graytone mask profile of a mask substrate;
 - generating a graytone mask pattern of the mask substrate, wherein mask structures are disposed on a surface of the mask substrate that correspond to the graytone mask pattern;
 - exposing an optical device resist by projecting a light through a graytone mask comprising the graytone mask pattern, the optical device resist is disposed over an optical device substrate; and
 - wherein the optical device resist has a varying thickness corresponding to the graytone mask pattern after developing the optical device resist.
2. The method of claim 1, wherein the graytone mask pattern comprises a resist thickness profile.
3. The method of claim 1, wherein the graytone mask is patterned based on a certain pattern density of the graytone mask profile.
4. The method of claim 1, wherein the graytone mask pattern is generated by a design target or a previous optical device profile.
5. The method of claim 1, wherein a diffuser is added on the graytone mask.
6. The method of claim 1, wherein the optical device resist corresponds to a thickness to be formed in the optical device substrate upon etching of the optical device resist and the optical device substrate.
7. The method of claim 1, wherein projecting the light through the graytone mask further comprises projecting the light through a hardmask.
8. The method of claim 1, wherein the mask structures are disposed on a bottom surface of the mask substrate.

9. The method of claim 1, further comprising adjusting the graytone mask pattern by adjusting a critical dimension of the graytone mask.
10. The method of claim 1, further comprising adjusting the graytone mask pattern by adjusting a pitch of the graytone mask.
11. The method of claim 1, wherein the mask structures comprise an absorption material.
12. The method of claim 1, wherein the mask structures comprise a reflective material.
13. A method of optical device fabrication, comprising:
identifying a graytone mask profile of a mask substrate;
generating a graytone mask pattern of the mask substrate, wherein print structures are disposed on a diffuser coupled to a surface of the mask substrate that correspond to the graytone mask pattern;
exposing an optical device resist by projecting a light through a graytone mask comprising the graytone mask pattern, the graytone mask disposed over the optical device resist is disposed over an optical device substrate; and
wherein the optical device resist has a varying thickness corresponding to the graytone mask pattern after developing the optical device resist.
14. The method of claim 13, wherein projecting the light through the graytone mask further comprises projecting the light through a hardmask.
15. The method of claim 13, wherein the print structures are disposed on a top surface of the diffuser.
16. The method of claim 13, wherein the print structures are disposed on a bottom surface of the diffuser.
17. The method of claim 13, wherein the print structures on the diffuser are disposed on the diffuser corresponding to the graytone mask profile.

18. The method of claim 13, wherein the print structures comprise an intensity map.
19. The method of claim 13, wherein the print structures are printed on the diffuser.
20. The method of claim 13, wherein the print structures comprise an absorption material.
21. The method of claim 13, wherein the print structures comprise a reflective material.
22. The method of claim 13, wherein the optical device resist corresponds to a thickness to be formed in the optical device substrate upon etching of the optical device resist and the optical device substrate.
23. A method of optical device fabrication, comprising:
identifying a graytone mask profile of a mask substrate;
generating a graytone mask pattern of the mask substrate, wherein print structures are disposed on a dose adjustment layer coupled to a diffuser and a surface of the mask substrate that correspond to the graytone mask pattern;
exposing an optical device resist by projecting a light through a graytone mask comprising the graytone mask pattern, the optical device resist is disposed over an optical device substrate; and
wherein the optical device resist has a varying thickness corresponding to the graytone mask pattern after developing the optical device resist.
24. The method of claim 23, wherein the dose adjustment layer comprises a transparent substrate.
25. The method of claim 23, wherein the print structures are disposed on a top surface of the dose adjustment layer.

26. The method of claim 23, wherein the print structures are disposed on a bottom surface of the dose adjustment layer.

27. The method of claim 23, wherein the print structures on the dose adjustment layer are disposed on the dose adjustment layer corresponding to the graytone mask profile.

28. The method of claim 23, wherein the print structures comprise an intensity map.

29. The method of claim 23, wherein the print structures are printed on the dose adjustment layer.

30. The method of claim 23, wherein the print structures comprise an absorption material.

31. The method of claim 23, wherein the print structures comprise a reflective material.

32. The method of claim 23, wherein projecting the light through the graytone mask further comprises projecting the light through a hardmask.

33. The method of claim 23, wherein the optical device resist corresponds to a thickness to be formed in the optical device substrate upon etching of the optical device resist and the optical device substrate.