



- (51) **International Patent Classification:**
G02B 5/30 (2006.01) *G02B 1/11* (2006.01)
- (21) **International Application Number:**
PCT/US2017/017319
- (22) **International Filing Date:**
10 February 2017 (10.02.2017)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
- (30) **Priority Data:**
62/303,969 4 March 2016 (04.03.2016) US
62/401,451 29 September 2016 (29.09.2016) US
- (71) **Applicant:** APPLIED MATERIALS, INC. [US/US];
3050 Bowers Avenue, Santa Clara, California 95054 (US).
- (72) **Inventors:** MARKLE, David; 3528 Streamside Circle,
Pleasanton, California 94588 (US). CHEN, Jang Fung;
11752 Pine Brook Lane, Cupertino, California 95014 (US).
- (74) **Agents:** PATTERSON, B. Todd et al.; Patterson &
Sheridan, L.L.P., 24 Greenway Plaza, Suite 1600, Houston,
Texas 77046 (US).

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

(84) **Designated States** (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

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

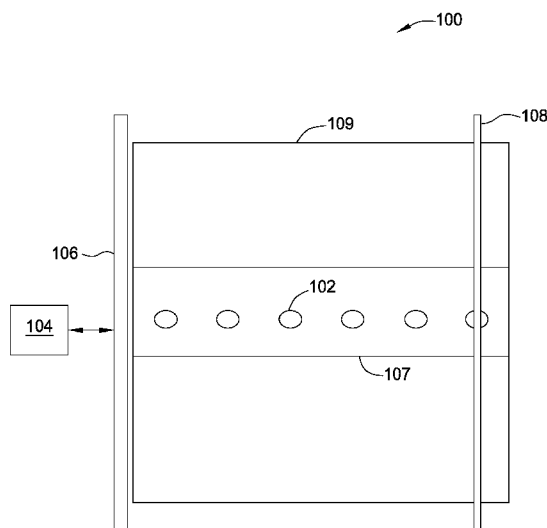
(54) **Title:** WIRE GRID POLARIZER MANUFACTURING METHOD

FIG. 1

(57) **Abstract:** The present disclosure generally relates to systems and methods for manufacturing wire grid polarizers for LCDs using interference lithography, which are also useful for generating large-area grating patterns. In one embodiment, a method includes depositing a bottom anti-reflective coating layer over an aluminum coated flat panel display substrate, depositing a photoresist layer over the bottom anti-reflective coating layer, and exposing the photoresist layer with an image from a phase grating mask. The exposure with the phase grating mask is done by imaging the ± 1 diffraction orders from the phase grating mask onto the substrate using a half Dyson optical system. A plurality of half Dyson systems are generally used in parallel to pattern fine geometry lines and spaces of a wire grid polarizer for a large area substrate. Each half Dyson system includes a primary mirror, a positive lens and a reticle.

WIRE GRID POLARIZER MANUFACTURING METHOD

BACKGROUND

Field

[0001] Embodiments of the present disclosure generally relate to flat panel display manufacturing processes. More specifically, systems and methods for manufacturing wire grid polarizers for liquid crystal displays are disclosed.

Description of the Related Art

[0002] A liquid crystal display (LCD) is a display that uses the light-modulating properties of liquid crystals sandwiched between crossed polarizers to display images. LCDs are used in a wide range of applications, including, but not limited to, high definition televisions, computer monitors and mobile devices. In a typical LCD, the liquid crystal cells are aligned between two linear polarizers, which are oriented orthogonally to one another.

[0003] Polarizing films have been used as the linear polarizers. The polarizing films allow light polarized perpendicular to the conductor lines of the polarizer to pass through, while reflecting the light polarized parallel to the conductor lines of the polarizer. However, polarizing films are very costly. In fact, polarizing films often account for more than 30% of the total cost of an LCD panel. Accordingly, wire grid polarization has been used to polarize the LCD. Wire grid polarization consists of directly patterning the glass substrate with a wire grid rather than applying additional films. Wire grid polarizers use an array of finely patterned wires, which is patterned onto the glass substrate, to selectively transmit light having an electric vector perpendicular to the grid lines while reflecting light having an electric vector in a parallel direction. However, fine patterning of a very large LCD panel is very challenging.

[0004] Therefore, there is a need in the art for systems and methods for generating wire grid polarizers for LCDs.

SUMMARY

[0005] The present disclosure generally relates to systems and methods for manufacturing wire grid polarizers for LCDs using interference lithography, which are also useful for generating large-area grating patterns. In one embodiment, a method includes depositing a bottom anti-reflective coating layer over an aluminum coated flat panel display substrate, depositing a photoresist layer over the bottom anti-reflective coating layer, and exposing the photoresist layer with an image from a phase grating mask. The exposure with the phase grating mask is done by imaging the ± 1 diffraction orders from the phase grating mask onto the substrate using a half Dyson optical system. A plurality of half Dyson systems are generally used in parallel to pattern fine geometry lines and spaces of a wire grid polarizer for a large area substrate. Each half Dyson system includes a primary mirror, a positive lens and a reticle.

[0006] In one embodiment, a system for patterning a flat panel display is disclosed. The system includes a laser gage, a laser gage mirror and a plurality of half Dyson systems. Each half Dyson system includes a primary mirror, a positive lens, and a reticle.

[0007] In another embodiment, a method is disclosed. The method includes depositing an aluminum layer and then a bottom anti-reflective coating layer over a substrate, depositing a photoresist layer over the anti-reflective coating layer, patterning the photoresist layer using a phase grating mask, and imaging the ± 1 diffraction orders from the phase grating mask onto the substrate. Patterning with the phase grating mask includes directing a laser illumination beam through an opening in the center of a primary mirror to a reticle and diffracting the laser illumination beam from the reticle to opposing areas near an edge of the primary mirror. The beams from the opposing areas are combined at the substrate and interfere to create a grating pattern having twice the spatial frequency as the grating on the phase grating mask.

[0008] In yet another embodiment, a method is disclosed. The method includes depositing a bottom anti-reflective coating layer over an aluminum

coated substrate, depositing a photoresist layer over the bottom anti-reflective coating layer, patterning the photoresist layer with a first pattern by imaging two diffraction orders onto the substrate. Patterning the first pattern comprises directing a laser illumination beam through an opening in a center of a primary mirror to a reticle and diffracting the laser illumination beam from the reticle through refractive components to two opposing areas near an edge of the primary mirror. This is followed by a photoresist development operation, an etching operation and an operation that removes the remaining photoresist and anti-reflective coating layers. In this particular case the exposure and etching operations are arranged trenches in the aluminum coating that are one-quarter of the grating period on the substrate. Imaging the substrate comprises patterning the photoresist layer with a second identical pattern positioned so in the trenches created by the second identical pattern fall midway between the trenches of the first pattern. As with the first exposure the exposure and etch parameters are arranged to produce trenches that are about one-quarter of the period of the grating on the substrate. After the development, etching, and stripping operations, the result is a grid of fine aluminum lines having a grating period that is half of the period created by either exposure operation.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] 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 typical embodiments of this disclosure and are therefore not to be considered limiting of its scope, for the disclosure may admit to other equally effective embodiments.

[0010] Figure 1 is a lithography system for printing a wire grid polarizer pattern onto a flat panel display substrate.

[0011] Figure 2A is a half Dyson system of the system of Figure 1.

[0012] Figure 2B is an enlarged view of a portion of the half Dyson system of Figure 2A.

[0013] Figure 2C is an enlarged view of a portion of the portion of the half Dyson system of Figure 2B.

[0014] Figure 3 is a plan view of a primary mirror, which may be used in the half Dyson system of Figure 2A.

[0015] Figure 4 is a flow diagram summarizing a method according to one embodiment.

[0016] Figures 5A-5I depict schematic sectional side views of stages of fabrication of a wire grid polarizer on a flat panel display substrate according to embodiments described herein.

[0017] Figure 6 is a half Dyson optical system of the system of Figure 1 according to another embodiment.

[0018] Figure 7 is a graph illustrating an intensity profile of a diffraction limited laser illumination beam along a length of a phase grating mask.

[0019] Figure 8 is a graph illustrating an intensity profile the laser illumination beam along a grating line of the phase grating mask.

[0020] Figure 9 is a graph illustrating the variation in grating line height with distance from a center line on the phase grating mask.

[0021] To facilitate understanding, identical reference numerals have been used, wherever possible, to designate identical elements that are common to the Figures. Additionally, elements of one embodiment may be advantageously adapted for utilization in other embodiments described herein.

DETAILED DESCRIPTION

[0022] The present disclosure generally relates to systems and methods for manufacturing wire grid polarizers for LCDs using interference lithography,

which are also useful for generating large-area grating patterns. In one embodiment, a method includes depositing a bottom anti-reflective coating layer over an aluminum coated flat panel display substrate, depositing a photoresist layer over the bottom anti-reflective coating layer, and exposing the photoresist layer with an image from a phase grating mask. The exposure with the phase grating mask is done by imaging the ± 1 diffraction orders from the phase grating mask onto the substrate using a half Dyson optical system. A plurality of half Dyson systems are generally used in parallel to pattern fine geometry lines and spaces of a wire grid polarizer for a large area substrate. Each half Dyson system includes a primary mirror, a positive lens and a reticle.

[0023] Figure 1 is a system 100 for printing a wire grid polarizer pattern onto a flat panel display substrate. The system 100 includes a plurality of half Dyson systems 102 (six are shown), a laser gage 104, a laser gage mirror 106 and a substrate stage 109. The plurality of half Dyson systems 102 may be evenly distributed across the width of the substrate stage 109, which is configured to support a large area substrate. For example, when the system 100 is configured for patterning a Gen 8 flat panel display, having a width of about 2200 millimeters (mm) and a length of about 2500mm, the spacing between each of the half Dyson systems 102 may be about 367mm. The system 100 may be configured to pattern Gen 8, Gen 10 and future generation flat panel display substrates.

[0024] As shown in Figure 1, the system 100 has six half Dyson systems 102 corresponding to six columns across the width of the flat panel display substrate. In use, each column may operate in parallel to write a 13.3mm wide scan path 108 of the flat panel display substrate. The half Dyson systems 102 may be disposed on bridge 107, which is spaced above a substrate stage 109, as shown in Figure 1.

[0025] Figure 2A is a half Dyson system 102 of the system 100. The half Dyson system 102 includes a primary mirror 210, a positive lens 214, a meniscus lens 212, and a reticle 216. The primary mirror 210 may be a

weakly aspheric mirror. The positive lens 214 may be a glass lens or it may be made from a fused silica, calcium difluoride (CaF_2) crystal, or any other suitable material. The reticle 216 may have a height of between about 10mm and about 20mm, for example 14mm, and a thickness of between about 1mm and about 6.35mm, for example, about 2.286mm. Figure 2B is an enlarged view of a portion of the half Dyson system 102 of Figure 2A. Figure 2C is an enlarged view of a portion of the portion of the half Dyson system 102 of Figure 2B. As shown in Figure 2C, a flat panel display substrate 218 may be positioned adjacent to the reticle 216. The flat panel display substrate 218 is separated from the reticle 216 by a first air gap 217. The first air gap 217 may have a width of between about 0.1mm and about 0.5mm, for example, about 0.25mm. The reticle 216 may be separated from the positive lens 214 by a second air gap 215 or it may be optically coupled with an optical gel or optical cement or any other suitable material. The second air gap 215 may have a width of between about 0.1mm and about 0.5mm, for example, about 0.25mm. The second air gap 215 may also be filled with an optical gel or optical cement or any other suitable material. For example, a suitable material may have an index of refraction that matches the optical materials on either side at the exposure wavelength.

[0026] Figure 3 is a plan view of the primary mirror 210, which may be used in the half Dyson system 102. The primary mirror 210 may include an opening 330, which is centrally located, and through which the illumination beam 211 on the mask emerges and which is collimated on the reflective, phase grating mask to generate ± 1 diffraction orders 211b and 211c to occupy the area 332 located at the top edge, or a first side, of the primary mirror 210, and an area 334 located at the bottom edge, or opposite side, of the primary mirror 210. The ± 1 diffraction orders 211b and 211c from the grating in the object plane may ultimately be imaged just below the object plane on an opposite side of an optical axis. The zero diffraction order 211a, which should have a relatively small intensity, passes back through the opening 330 in the primary mirror 210. The zero diffraction order 211a is not imaged. In other words, the zero diffraction order 211a is eliminated, which

results in doubled frequency of grating lines to be imaged. The distance between the vertex of the primary mirror 210 and the substrate may be between about 50mm and about 500mm, for example, about 85mm. Larger optical systems yield larger field sizes and therefore require fewer columns to span a given field, but each optical system costs more. Thus, the field size may be a question of economics. The field size of the system shown in Figures 1 and 2A-2C is about 2mm by about 13.3mm and the numerical aperture (NA) is 0.8875, which is high for such an optical system. Increased NA is made possible because a very small portion of the primary mirror 210 is used, which improves the results of the design optimization process.

[0027] Figure 4 is a flow diagram summarizing a method, 400, according to one embodiment. Figures 5A-5E depict schematic sectional side views of stages of fabrication of a wire grid polarizer on a flat panel display substrate 218 according to embodiments described herein.

[0028] The method 400, shown in Figure 4, begins at operation 410 by depositing a bottom anti-reflective coating (BARC) layer 560 over flat panel display substrate 218, which may have an aluminum coating 561, as shown in Figure 5A. The BARC layer 560 may be deposited on and in contact with the aluminum-coated flat panel display substrate 218. The BARC layer 560 may include any suitable BARC material(s). The BARC layer 560 may include a material which absorbs 355nm light and is transparent to 400nm and above light, such that the BARC layer 560 may remain in place throughout the method 400 until photoresist layer 562, discussed below, is stripped away from an etched line pattern. Deposition of the BARC layer 560 provides for control of the critical dimension (CD) across the surface of the flat panel display substrate 218.

[0029] At operation 420, a photoresist layer 562 is deposited over the BARC layer 560, as shown in Figure 5B. The photoresist layer 562 may be deposited on and in contact with the BARC layer 560. The photoresist layer 562 may include any suitable photoresist material(s).

[0030] At operation 430, two diffraction orders, ± 1 diffraction orders, from a phase grating mask are projected from in a first portion 216a of the reticle 216 onto the substrate 218, as shown in Figure 2B. Specifically, a laser illumination beam 211 is projected through the opening 330 of the primary mirror 210, as shown in Figures 2A and 2B. The opening 330 in the primary mirror 210 is in the same location as where the zero diffraction order 211a would fall, thus preventing any zero diffraction order from reaching the substrate. By eliminating the zero diffraction order, the frequency of the grating lines to be imaged is doubled. The laser may be a commercially available 16 watt (W)/355 nanometer (nm) lasers. The laser illumination beam 211 passes through the primary opening 330, and through the positive lens 214 to create a normally incident, collimated beam on the reticle 216.

[0031] More particularly, the laser illumination beam 211 diffracts from the bottom surface of the reticle 216, where the phase grating mask is located, and the ± 1 diffraction orders 211b and 211c proceed to the two areas 332 and 334 on opposite sides near the edge of the primary mirror 210 as shown in Figure 2. On reflection from the primary mirror and after passing through the refractive components a second time the ± 1 diffraction orders 211b and 211c are collimated and superimposed where they interfere to form a fringe pattern on the substrate 218 having twice the spatial frequency as the grating pattern on the reticle 216.

[0032] After the flat panel display substrate 218 has been imaged, the photoresist layer 562 of the flat panel display substrate 218 is developed to reveal the grating pattern. The method 400 further includes operation 440 transferring the resist pattern into the aluminum layer and stripping away the resist and antireflection layers. After stripping away the photoresist layer 562 and the BARC layer 560, all that remains is a fine grid of aluminum wires 561 on the substrate. The patterned photoresist layer 562 is illustrated in Fig. 5C, the pattern transfer operation in Fig 5D, and the resulting grid of aluminum wires 561 in Fig. 5E.

[0033] Because an array of, for example evenly distributed, Dyson systems 102 are employed in the system 100, the flat panel display substrate 218 is scanned under the half Dyson systems 102, using the substrate stage 109 and, at the end of scan, the flat panel display substrate 218 is stepped in an orthogonal direction and scanned in the opposite direction and so on to image a phase grating pattern over the entire flat panel display substrate 218.

[0034] In one example, when the system 100 is used to perform the method 400 for patterning a Gen 8 substrate, the scan path 108 may have a width of about 13.3mm. In order to pattern the entire substrate, at least about 30 scans must be performed. Scanning occurs by moving the substrate stage 109 under the plurality of half Dyson systems 102. The laser gage 104 uses the laser gage mirror 106 as a reference to precisely set and maintain the stepping distance to an integral number of fringes. Ideally the optical axis of the half Dyson systems 102 and the axis of the laser illumination beam should be arranged along a straight line on the substrate surface to minimize Abbe offset errors. The scan speed may be limited by the maximum stage velocity. The maximum stage velocity may be between about 0.1 meters/second (m/s) and about 3 m/s, for example about 2 m/s. Each scan may take about 1.66 seconds. Therefore, it may take about 49.8 seconds to scan and pattern an entire Gen 8 substrate.

[0035] The etched line width to grating period ratio can be reduced to about a 1:4 ratio by varying the exposure dose and etching system parameters. This leaves room in the remaining oversized aluminum lines to interleave a second exposure and etching operation that halves the resulting grating period. After the first pattern has been exposed, developed and etched then, operations 410 through 440 may be repeated to interleave a second identical pattern on the flat panel display substrate 218 with a second exposure.

[0036] The second exposure may be combined with a very slight adjustment of the image position so that the etch operation is centered on

each of the aluminum wires 561 generated with the first exposure. This is illustrated in Figures 5F to 5I. For example, after the method 400 has been completed once, the flat panel display substrate 218 may have 150nm lines with a 200nm pitch. The substrate position for the second exposure would be, offset from the first position by 100nm. After operations 430 and 440 have been repeated using the same phase grating mask, the flat panel display substrate 218 would have an equal line and space pattern having a 100 nm period.

[0037] The width of the trenches created in the aluminum layer depends on the resist parameters, the exposure dose and the etching parameters. For example if a positive acting resist is used, then a smaller exposure dose and a less aggressive etch may be used to achieve narrower trenches.

[0038] Figure 6 is a half Dyson system 602 which may be used in the system 100 according to another embodiment. The half Dyson system 602 includes a primary mirror 610, a positive lens 614, and a reticle 616. The primary mirror 610 may be a weakly aspheric mirror. The positive lens 614 may be a glass lens. The reticle 616 may have a height of between about 10mm about 20mm, for example 14mm, and a thickness of between about 1 mm and about 6.35 mm, for example, about 2.286mm. Laser illumination beam 611 passes through the through the positive lens 614 to create a normally incident, collimated beam incident on the reticle 616.

[0039] While the above embodiments contemplate use of the process for manufacturing polarizers, the process disclosed may also be used for manufacturing gratings which have found a wide variety of applications including metrology and high-power laser beam compression and stretching. Further, the methods and systems described herein may be used in conjunction with self-aligning imprint lithography (SAIL). SAIL processes have high-throughput and high-yield, and are more cost-efficient. SAIL includes a three operation process flow consisting of material deposition, imprinting with a mask and etching. Specifically, the methods and systems may be used to

form the phase grating of SAIL masks or SAIL may be used to form the phase grating of the methods described herein.

[0040] It is another object of the present disclosure to provide uniform illumination across the field. The laser illumination beam 211 is Gaussian shaped. In order to provide a uniform exposure dose across the field, the Gaussian shape of the laser illumination beam 211 may be used to illuminate a grating in which the lines vary in length depending on the intensity of the illumination beam at that point.

[0041] Figure 7 is a graph illustrating a Gaussian profile of a laser illumination beam 211 along a grating length. Portion 770 of the curve represents the portion of the laser illumination beam 211 that is not overlapped with the adjacent beam. End portions 780a and 780b represent portions of the curve that are overlapped with the adjacent beam. The exposure dose of end portions 780a and 780b are linearly tapered from 100% to 0% so overlapping exposures result in a uniform dose in the overlapped area. Tapering the end portions 780a and 780b provides for overlapping exposure doses that appear to be seamless, because small overlap errors do not generate abrupt exposure differences.

[0042] Figure 8 is a graph illustrating a profile of a laser illumination beam 211 along a grating line. More particularly, Figure 8 illustrates the profile of the laser illumination beam 211 at the longest grating line at that profile.

[0043] Figure 9 is a graph illustrating the variation in grating line height (or length) with distance from a center line. In order to control exposure dose, the laser illumination beam 211 is most intense in the center, so the grating lines closest to the center are shorter, or have less height, for example about .03mm. As you move along the grating towards the edge of the field, the length of the grating lines may get progressively longer, or the height may increase, for example about .1mm long. Varying the length of the grating line inversely to the integrated intensity of the laser illumination beam 211, as shown in Figures 7-8, results in providing the same exposure dose across the

field. The exposure dose is the integrated intensity over the time a point on the substrate is exposed. Exposure time is proportional to the length, or height, of the grating line.

[0044] By changing the lengths of the grating lines across the field as shown in Figures 7-9, the exposure dose over the substrate may be controlled. More particularly, the variation of the lengths of the grating lines across the field results in a uniform exposure dose from one end of the grating to the other despite the fact that the laser illumination beam 211 has a very non-uniform, Gaussian shape.

[0045] 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 system for patterning a flat panel display, comprising:
a laser gage;
a laser gage mirror; and
a plurality of half Dyson systems, wherein each half Dyson system comprises:
a primary mirror;
a positive lens; and
a reticle.
2. The system of claim 1, wherein the positive lens comprises fused silica or calcium difluoride.
3. The system of claim 1, further comprising:
a meniscus lens; and
a substrate stage.
4. The system of claim 3, further comprising a bridge, the bridge being spaced above the substrate stage and having a plurality of half Dyson systems disposed thereon.
5. The system of claim 1, wherein the primary mirror has an opening in a center for providing access to an illumination beam, the illumination beam illuminates an object grating with collimated light and provides a means of eliminating any zero order diffraction.
6. The system of claim 1, wherein the primary mirror reflects ± 1 diffraction orders from a grating in an object plane.
7. A method, comprising:
depositing a bottom anti-reflective coating layer over an aluminum coated substrate;
depositing a photoresist layer over the bottom anti-reflective coating layer;

patterning the substrate by imaging a phase mask grating onto the substrate, wherein patterning the substrate comprises:

directing a laser illumination beam through an opening of a primary mirror to a reticle containing the phase mask grating; and

diffracting the laser illumination beam from the reticle to opposing areas near edges of the primary mirror; and

imaging ± 1 diffraction orders onto the substrate.

8. The method of claim 7, wherein the bottom anti-reflective coating layer is deposited on and in contact with the aluminum coated substrate, and wherein the photoresist layer is deposited on and in contact with the bottom anti-reflective coating layer.

9. The method of claim 7, wherein the bottom anti-reflective coating layer comprises a material which absorbs 355nm light and is transparent to 400nm and above light.

10. The method of claim 7, further comprising:
developing the photoresist layer.

11. The method of claim 7, further comprising:
performing aluminum etching over the substrate.

12. A grating line pattern, comprising:
a center line; and
a plurality of grating lines, each grating line being a distance from the center line, a height of each of the plurality of grating lines increases as the distance from the center line increases to a point a distance away from the center line.

13. The grating line pattern of claim 12, wherein the height of a grating line proximal to the center line is less than the height of a grating line distal to the center line.

14. The grating line pattern of claim 13, wherein the height of the grating line is inversely proportional to an intensity of a Gaussian shaped laser illumination beam,

and wherein the height of the grating line is proportional to a time of exposure to a laser illumination beam.

15. The grating line pattern of claim 12, wherein the heights of the grating lines distal to the center line after the point the distance away from the center line are tapered to 0 mm.

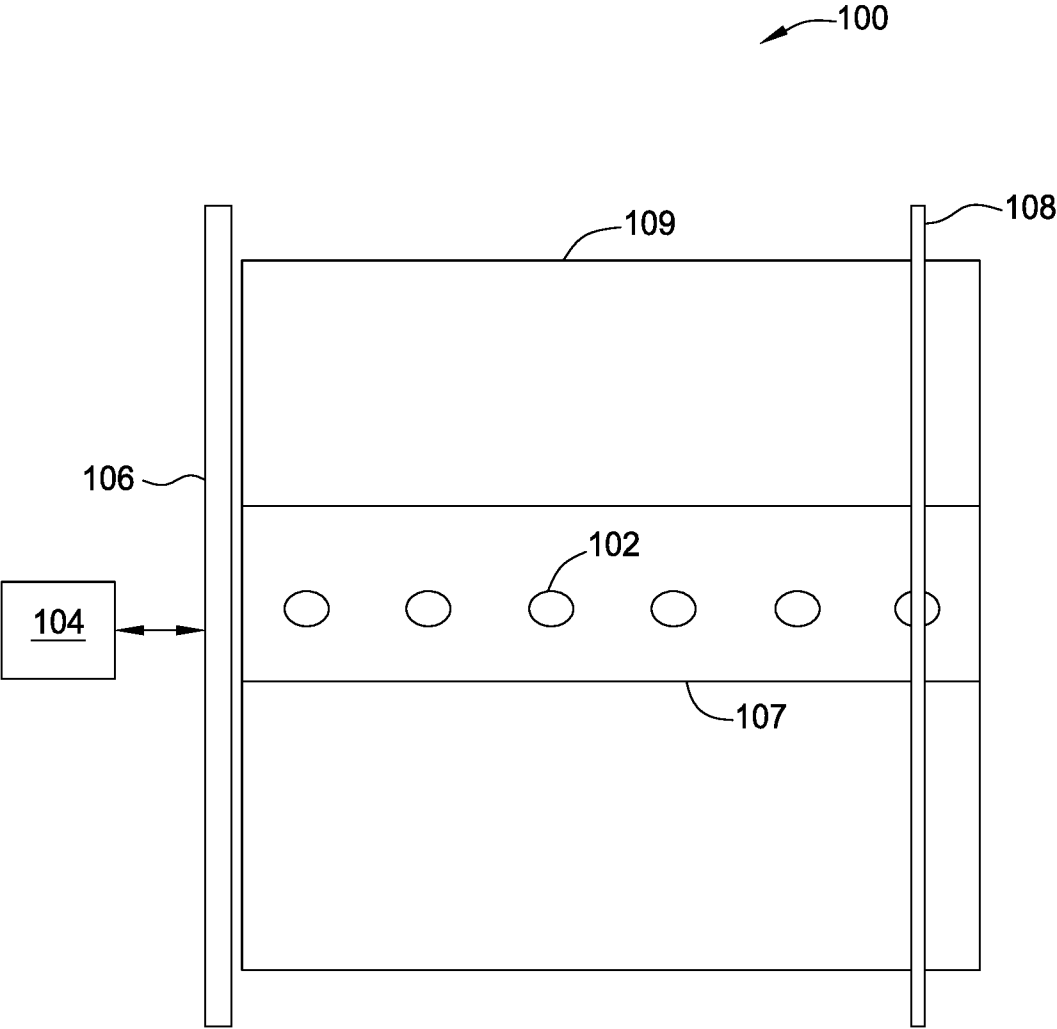


FIG. 1

FIG. 2A

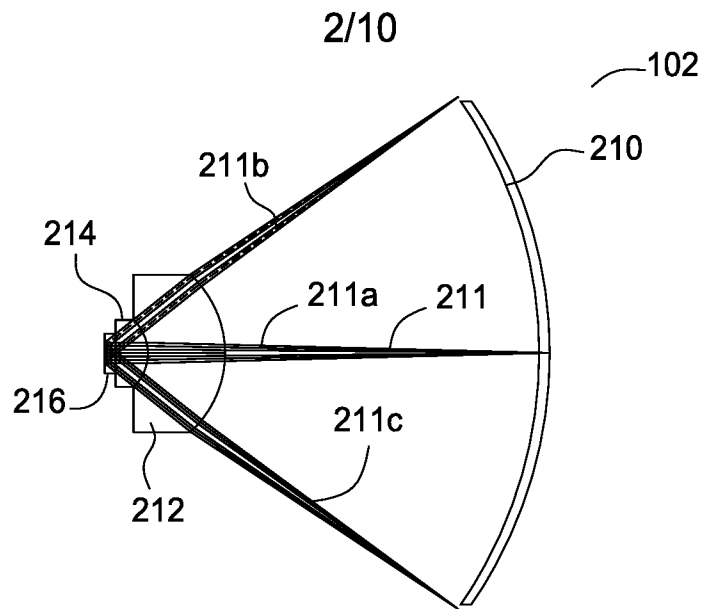


FIG. 2B

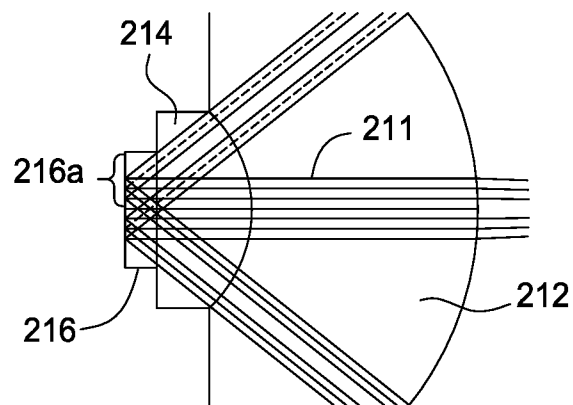
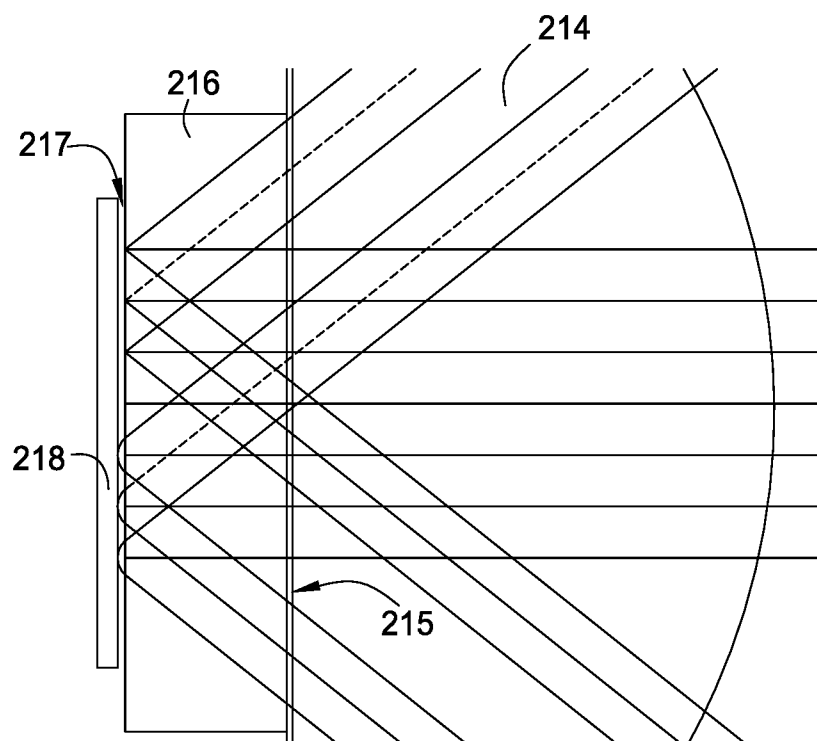


FIG. 2C



3/10

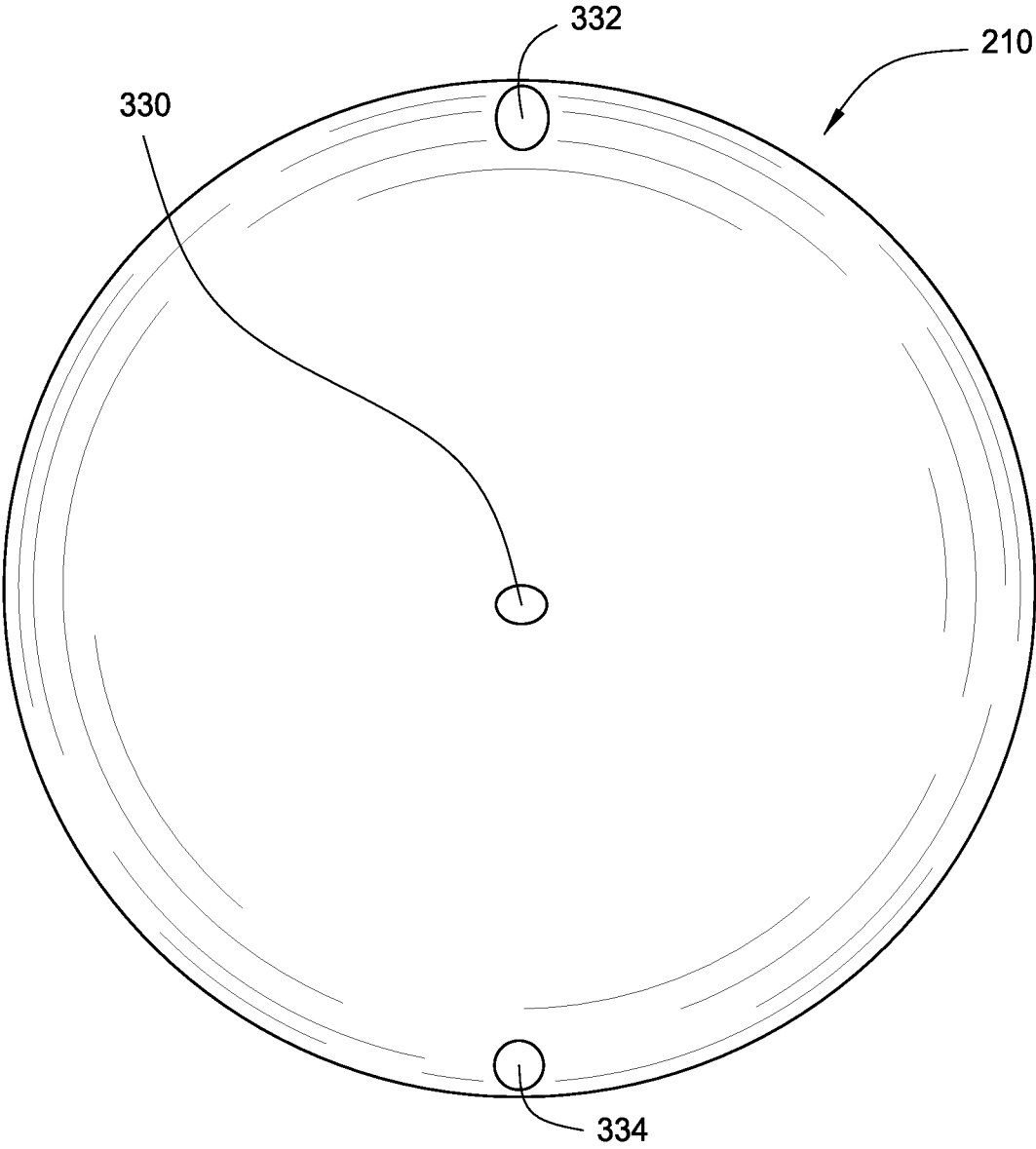


FIG. 3

4/10

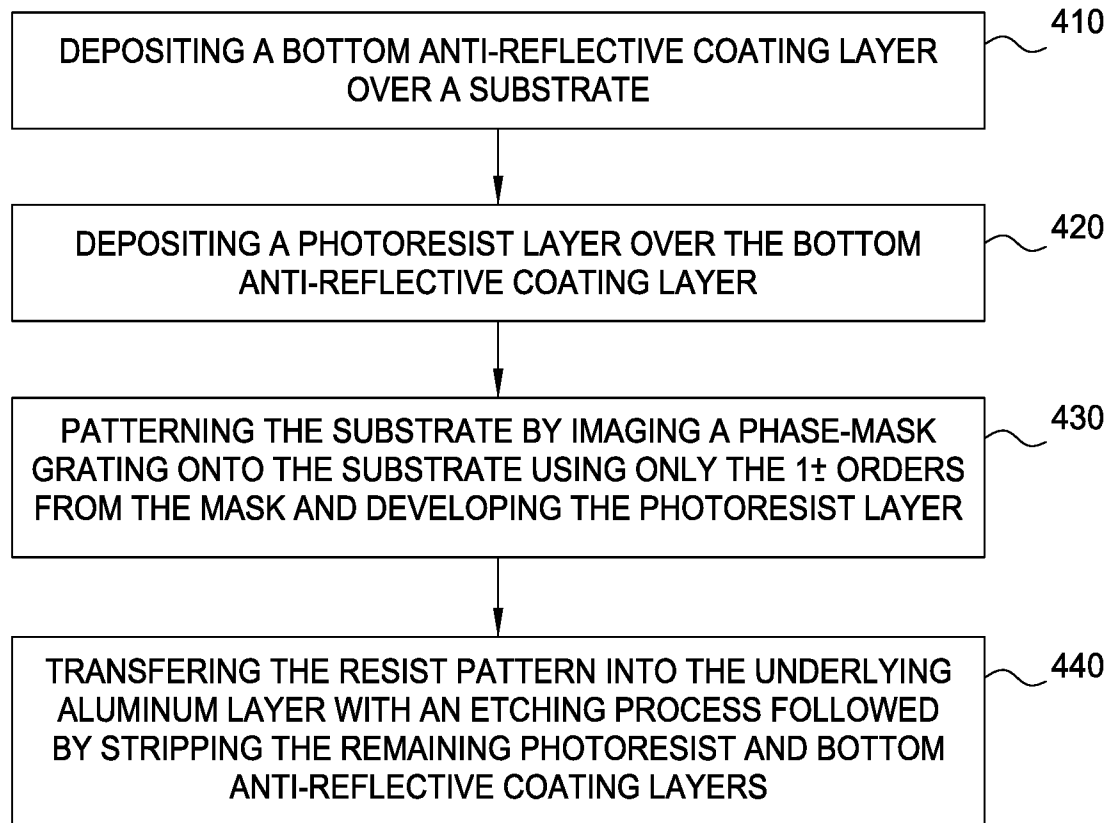


FIG. 4

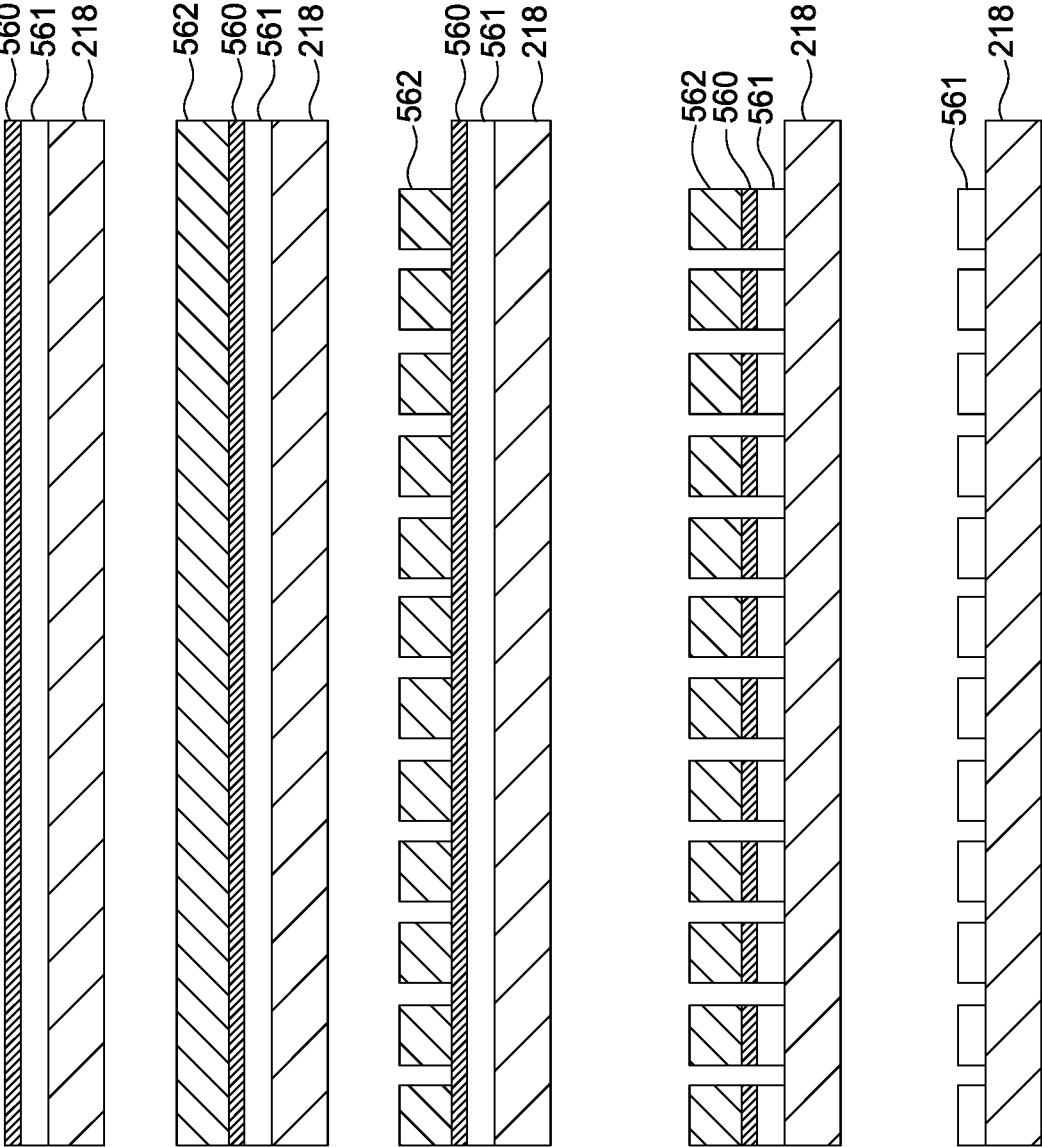


FIG. 5A

FIG. 5B

FIG. 5C

FIG. 5D

FIG. 5E

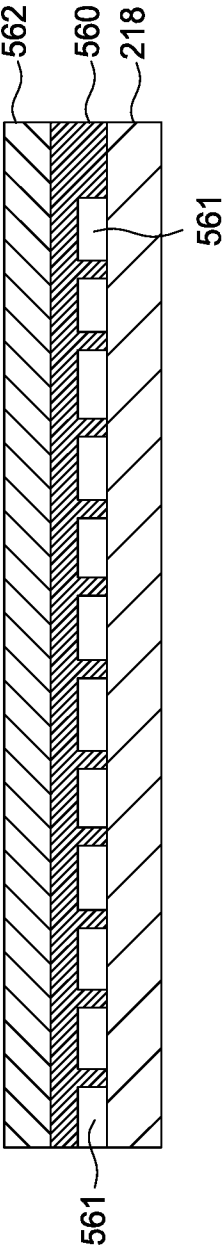


FIG. 5F

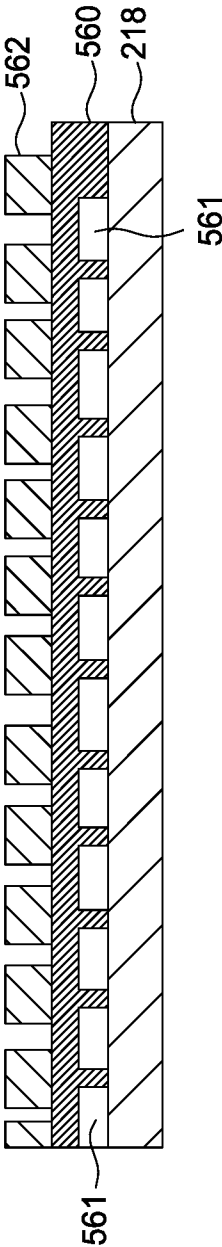


FIG. 5G

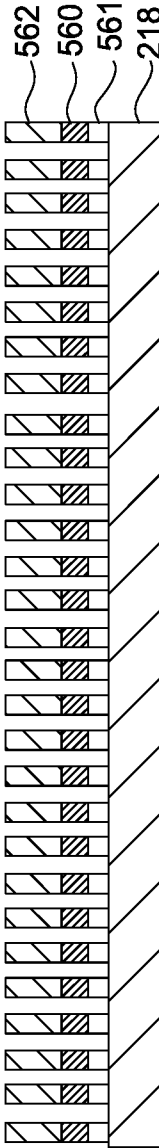


FIG. 5H

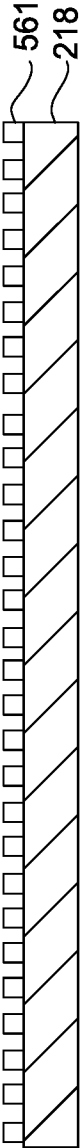


FIG. 5I

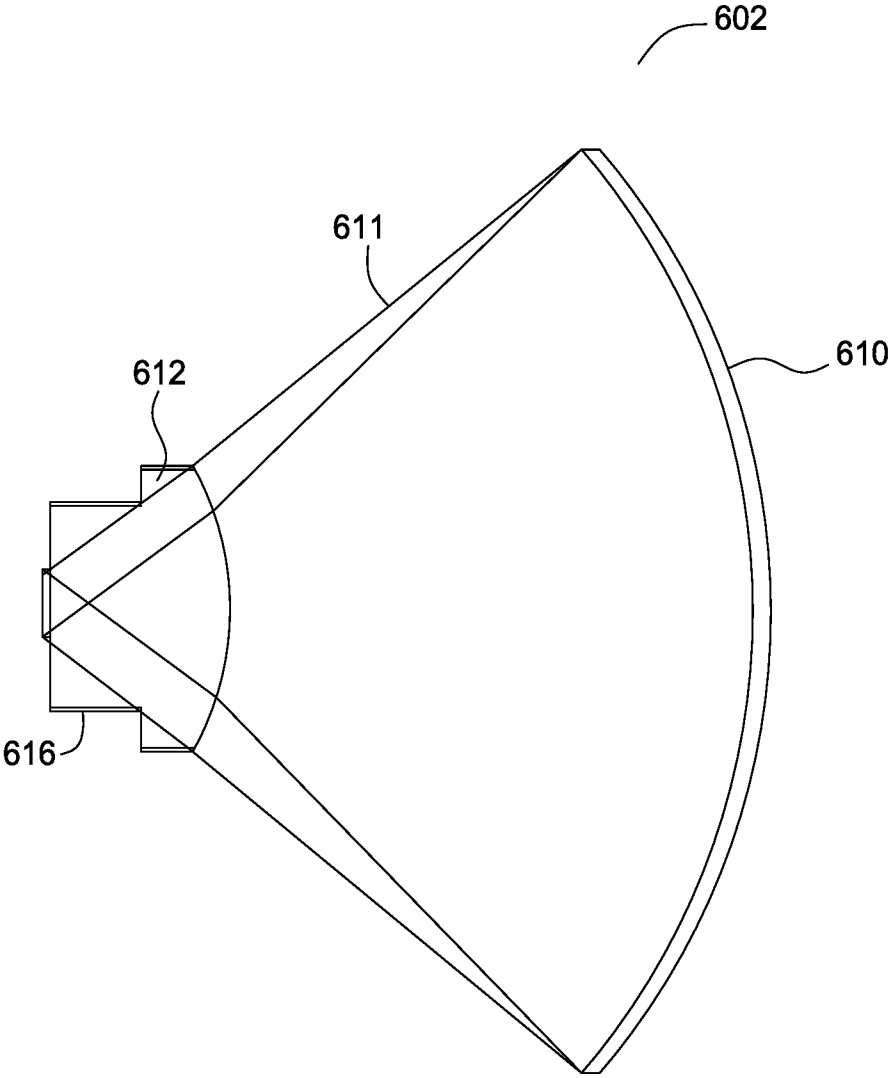


FIG. 6

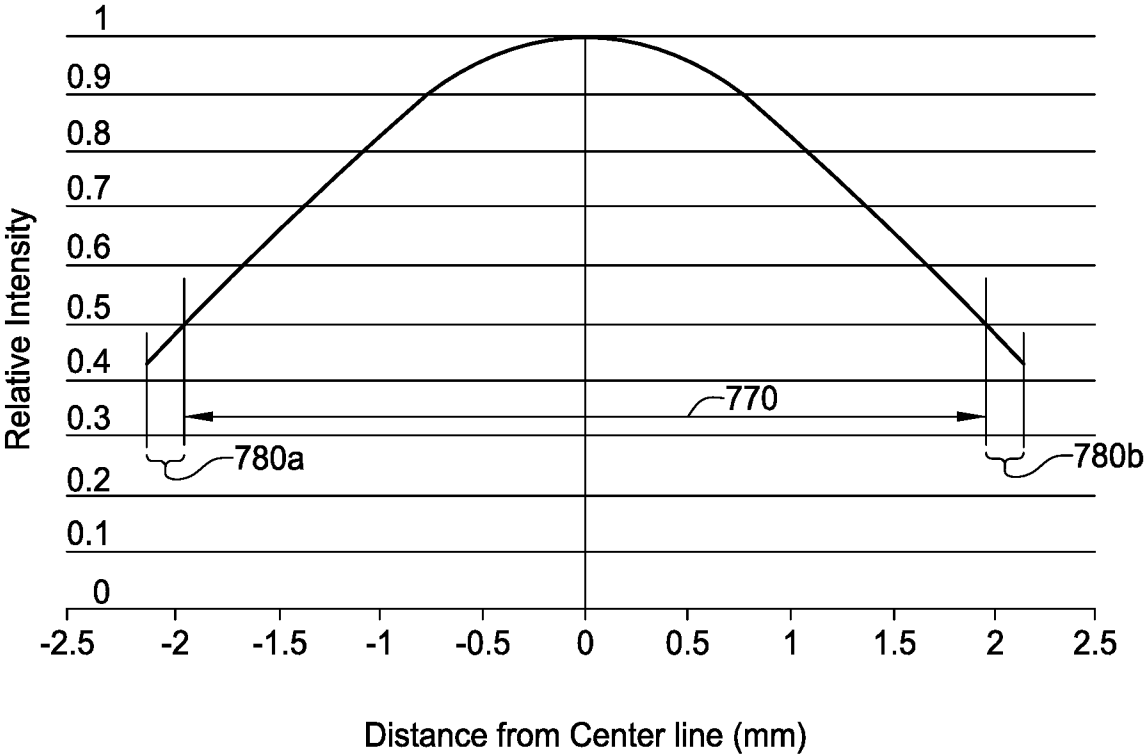


FIG. 7

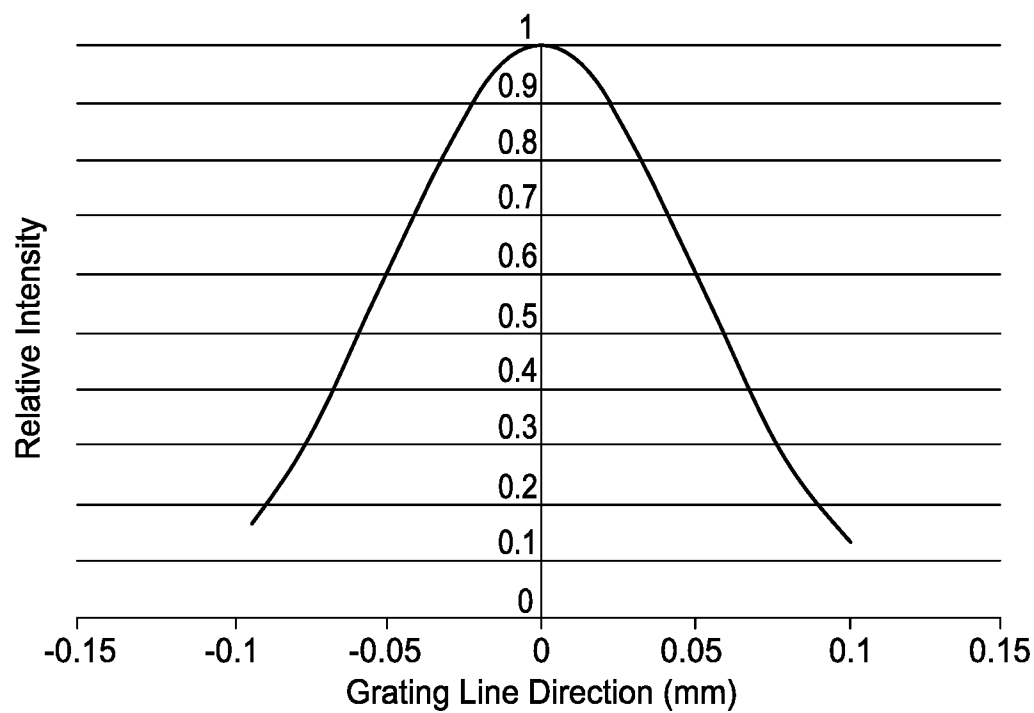


FIG. 8

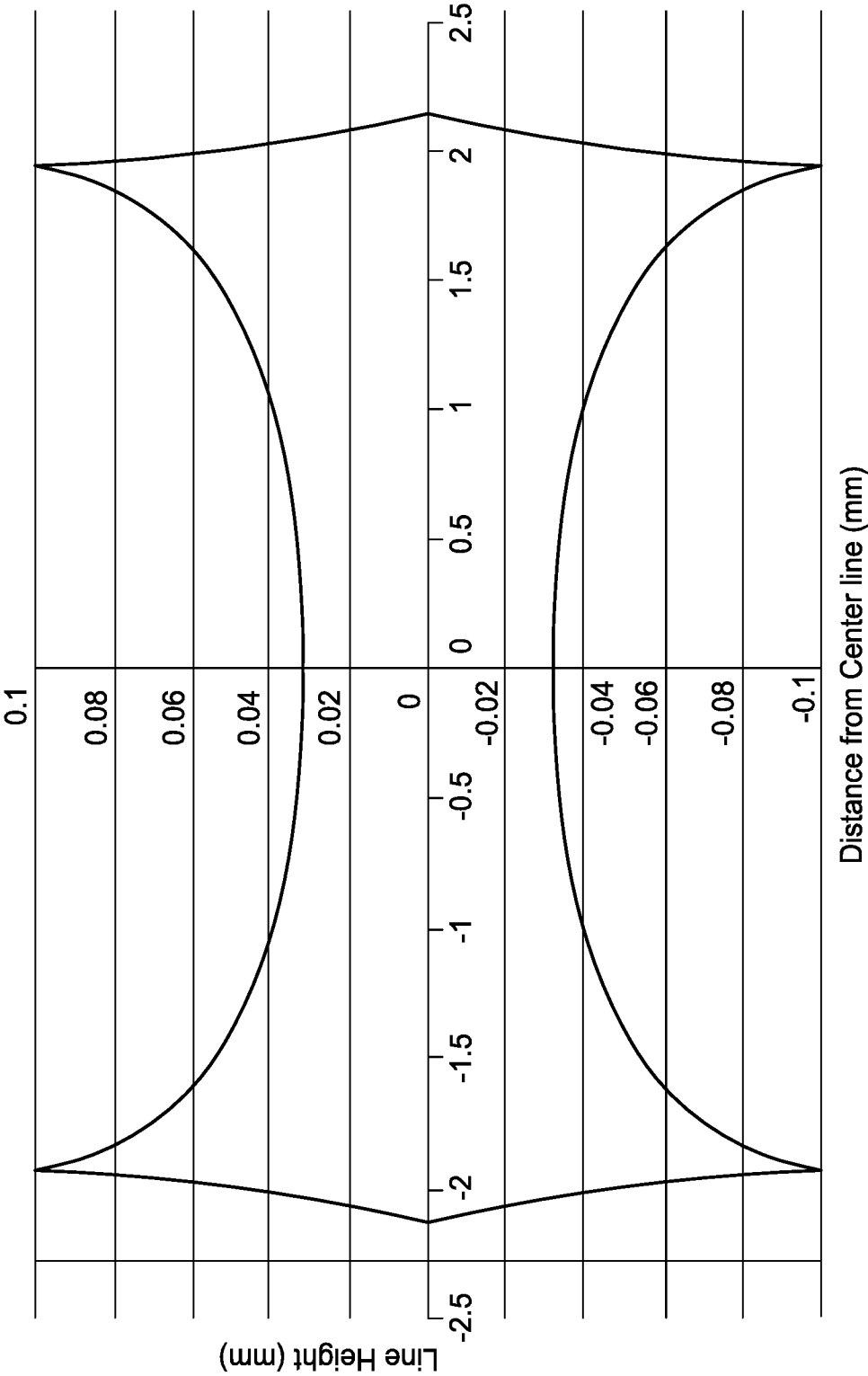


FIG. 9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2017/017319**A. CLASSIFICATION OF SUBJECT MATTER****G02B 5/30(2006.01)i, G02B 1/11(2006.01)i**

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G02B 5/30; B29D 11/00; G02F 1/1335; G02B 1/11

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords: polarizer, pattern, laser, lens, mirror, reticle

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2004-0169924 A1 (FLAGELLO et al.) 02 September 2004 See paragraphs [0014], [0030], [0062]-[0065], [0071], [0077]-[0084]; and figures 1, 4, 8-9.	1-6, 12-15
Y		7-11
Y	US 2013-0153534 A1 (MOLECULAR IMPRINTS, INC.) 20 June 2013 See paragraph [0038]; claim 1; and figure 6A.	7-11
A	EP 1684099 A2 (LG ELECTRONICS INC.) 26 July 2006 See figures 1-4.	1-15
A	US 2007-0165307 A1 (PERKINS) 19 July 2007 See figures 1a-2, 9a.	1-15
A	US 2008-0094547 A1 (SUGITA et al.) 24 April 2008 See figures 1-3.	1-15



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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

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

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

25 April 2017 (25.04.2017)

Date of mailing of the international search report

25 April 2017 (25.04.2017)

Name and mailing address of the ISA/KR

International Application Division

Korean Intellectual Property Office

189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea

Facsimile No. +82-42-481-8578

Authorized officer

KANG, Sung Chul

Telephone No. +82-42-481-8405



INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2017/017319

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2004-0169924 A1	02/09/2004	CN 1661478 A	31/08/2005
		JP 2004-258670 A	16/09/2004
		JP 2009-009143 A	15/01/2009
		JP 4832477 B2	07/12/2011
		KR 10-0597039 B1	04/07/2006
		TW 200528927 A	01/09/2005
		TW I319124 B	01/01/2010
		US 2004-0227923 A1	18/11/2004
		US 2005-0180008 A1	18/08/2005
		US 2005-0259324 A1	24/11/2005
		US 6943941 B2	13/09/2005
		US 7206059 B2	17/04/2007
		US 7221501 B2	22/05/2007
		US 7511884 B2	31/03/2009
US 2013-0153534 A1	20/06/2013	CN 104221127 A	17/12/2014
		JP 2015-502668 A	22/01/2015
		KR 10-2014-0117425 A	07/10/2014
		SG 10201608504S A	29/12/2016
		SG 11201403060W A	26/09/2014
		TW 201335970 A	01/09/2013
		US 9452574 B2	27/09/2016
		WO 2013-096459 A1	27/06/2013
EP 1684099 A2	26/07/2006	CN 1866062 A	22/11/2006
		EP 1684099 A3	02/08/2006
		JP 2006-201782 A	03/08/2006
		KR 10-0656999 B1	13/12/2006
		KR 10-2006-0084304 A	24/07/2006
		US 2006-0159958 A1	20/07/2006
US 2007-0165307 A1	19/07/2007	AU 2005-314134 A1	15/06/2006
		CN 101073024 A	14/11/2007
		CN 101688938 A	31/03/2010
		CN 101688938 B	05/06/2013
		CN 101688939 A	31/03/2010
		CN 101688939 B	17/07/2013
		CN 103033870 A	10/04/2013
		CN 103033870 B	03/08/2016
		EP 1820051 A1	22/08/2007
		EP 2158504 A1	03/03/2010
		EP 2158506 A1	03/03/2010
		JP 2008-523422 A	03/07/2008
		JP 2010-530994 A	16/09/2010
		JP 2010-531467 A	24/09/2010
		JP 2012-098738 A	24/05/2012
		JP 2012-256055 A	27/12/2012
		JP 4843617 B2	21/12/2011
		JP 5184624 B2	17/04/2013

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2017/017319

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2008-0094547 A1	24/04/2008	JP 5224252 B2	03/07/2013
		JP 5277455 B2	28/08/2013
		JP 5902389 B2	13/04/2016
		KR 10-1234986 B1	20/02/2013
		US 2006-0119937 A1	08/06/2006
		US 2008-0055549 A1	06/03/2008
		US 2008-0055719 A1	06/03/2008
		US 2008-0055720 A1	06/03/2008
		US 2008-0055721 A1	06/03/2008
		US 2008-0055722 A1	06/03/2008
		US 2008-0055723 A1	06/03/2008
		US 2008-0266662 A1	30/10/2008
		US 2008-0278811 A1	13/11/2008
		US 2009-0168171 A1	02/07/2009
		US 2010-0328769 A1	30/12/2010
		US 2010-0328770 A1	30/12/2010
		US 7570424 B2	04/08/2009
		US 7630133 B2	08/12/2009
		US 7800823 B2	21/09/2010
		US 7813039 B2	12/10/2010
		US 7961393 B2	14/06/2011
		US 8027087 B2	27/09/2011
		US 8755113 B2	17/06/2014
		WO 2006-063049 A1	15/06/2006
		WO 2008-076209 A1	26/06/2008
		WO 2009-002573 A1	31/12/2008
		WO 2009-002791 A1	31/12/2008
		JP 2008-102416 A	01/05/2008
		JP 4778873 B2	21/09/2011
		US 2011-0261455 A1	27/10/2011
		US 8049841 B2	01/11/2011
		US 8199282 B2	12/06/2012