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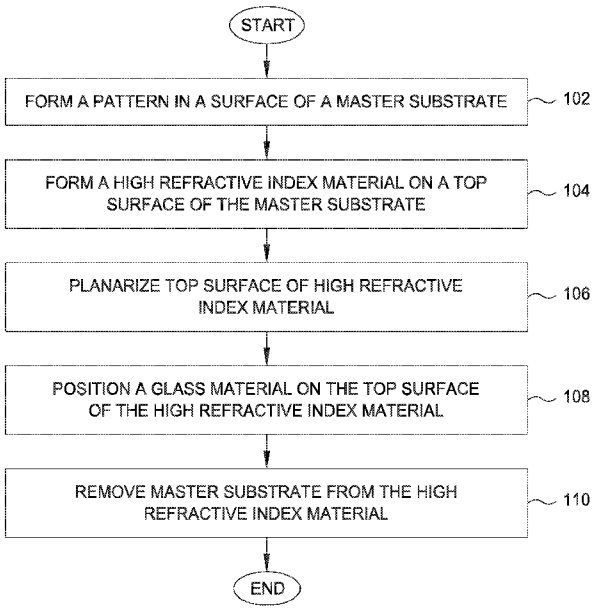
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(54) Title: METHOD FOR CREATING A HIGH REFRACTIVE INDEX WAVE GUIDE

100

FIG. 1



(57) Abstract: Embodiments described herein generally relate to a wave guide and a method of creating a wave guide. In one embodiment, a method of forming a wave guide is disclosed herein. An inverse master substrate having a plurality of projections extending therefrom is formed. A high refractive index material is formed on a top surface of the inverse master substrate. A glass layer is positioned on a top surface of the high refractive index material. The inverse master substrate is removed from the high refractive index material.

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[Continued on next page]

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METHOD FOR CREATING A HIGH REFRACTIVE INDEX WAVE GUIDE

BACKGROUND

Field

[0001] Embodiments of the present disclosure generally relates to a method and apparatus for patterning substrates. More specifically, embodiments of the present disclosure relate to a method of creating a wave guide for patterning a substrate.

Description of the Related Art

[0002] Photolithography is widely used in manufacturing of semiconductor devices and display devices, such as manufacturing liquid crystal displays (LCDs). Large area substrates are often used in the manufacture of LCDs. LCDs, or flat panels, are commonly used for active matrix displays, such as computers, touch panel devices, personal digital assistants (PDAs), cell phones, television monitors, and the like. Generally, flat panels may include a layer of liquid crystal material forming pixels sandwiched between two plates. When power from the power supply is applied across the liquid crystal material, an amount of light passing through the liquid crystal material may be controlled at pixel locations enabling images to be generated.

[0003] Pattern transfer by physical contact is a technique used for patterning substrates, including large area substrates. A wave guide is developed, and then physically applied to the substrate. The wave guide allows light to enter and exit the optical glass/material.

[0004] As the foregoing illustrates, there is a continual need for an improved technique for creating precise and cost-effective patterns on a substrate.

SUMMARY

[0005] Embodiments described herein generally relate to a wave guide and a method of creating a wave guide. In one embodiment, a method of forming a wave guide is disclosed herein. An inverse master substrate having a plurality

of projections extending therefrom is formed. A high refractive index material is formed on a top surface of the inverse master substrate. A glass layer is positioned on a top surface of the high refractive index material. The inverse master substrate is selectively removed from the high refractive index material.

[0006] In another embodiment, a method of forming a wave guide is disclosed herein. An inverse daughter substrate having a pattern of a plurality of projections extending therefrom is formed. The formation of the inverse daughter substrate includes forming an inverse master substrate having a pattern of a plurality of projections extending therefrom. The pattern of the inverse master is substantially equivalent to the pattern of the inverse daughter substrate. A high refractive index material is formed on a top surface of the inverse daughter substrate. A glass layer is positioned on a top surface of the high refractive index material. The inverse daughter substrate is selectively removed from the high refractive index material.

[0007] In another embodiment, a wave guide is disclosed herein. The wave guide includes a glass layer and a material. The glass layer has a refractive index of at least 1.4. The material is formed on a top surface of the glass layer. The material has a refractive index of at least 1.5. The material then has a pattern etched therein.

DETAILED DESCRIPTION OF THE DRAWINGS

[0008] So that the manner in which the above recited features of the present invention can be understood in detail, a more particular description of the invention, 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 invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

[0009] Figure 1 illustrates a method of forming a waveguide, according to one embodiment.

[0010] Figures 2A-2E illustrate side cross-sectional views of a waveguide at different stages of the method of Figure 1, according to one embodiment.

[0011] Figure 3 illustrates a method of forming a waveguide, according to one embodiment.

[0012] Figures 4A-4I illustrate side cross-sectional views of a waveguide at different stages of the method of Figure 3, according to one embodiment.

[0013] 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.

[0014] It is to be noted, however, that the appended drawings illustrate only exemplary embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

DETAILED DESCRIPTION

[0015] A method 100 for forming a wave guide is shown in Figure 1 which is a flow diagram that illustrates one embodiment, although the method is not limited to one embodiment. Figures 2A-2E illustrate cross-sectional views of a waveguide during different stages of manufacturing a master substrate 202 using the method 100, according to one embodiment.

[0016] In one embodiment, the master substrate 202 may be formed from a silicon material. At block 102 of Figure 1, a pattern 204 is formed on a surface of the silicon material. In the embodiment shown, the master substrate 202 has the pattern 204 formed in a top surface 206 of the master substrate 202, as shown in Figure 2B. The pattern 204 may be etched into the master substrate 202 using an etch process. For example, the pattern 204 may be etched into the master substrate 202 using an etch process that may produce a non-vertical trench and/or extrusions extending therefrom. The etch process forms the pattern 204 in the master substrate 202 such that an inverse master substrate 202 is formed. The inverse master substrate 202 is such that the master

substrate 202 includes a plurality of projections 208 protruding from the master substrate 202 and trenches 209 extending into the master substrate 202.

[0017] At block 104, a material 210 is formed on a top surface of the master substrate 202, as shown in Figure 2C. For example, a high refractive index (high-n) material is grown on the top surface 206 of the master substrate 202. In another embodiment, a high refractive index (high-n) material is conformally deposited on the top surface 206 of the master substrate 202. In some embodiments, the high-n material may be formed from an oxide, such as, for example, MoO_3, TiO_2, SiO, SiON, and the like. Generally, the material index may have a refractive index of greater than 1.55. In some embodiment, the material 210 may have an index substantially equal to that of glass (e.g., $n \approx 1.4 - 1.8$). In other embodiment, the material 210 may have a refractive index substantially greater than glass (e.g., $n > 1.7$).

[0018] At block 106, the master substrate 202 may undergo a chemical mechanical polishing (CMP) process. For example, the master substrate 202 may undergo a CMP process to planarize a top surface 212 of the material 210. Planarizing the top surface 212 of the material 210 may allow for a more robust bonding to other components of the waveguide.

[0019] At block 108, a glass material 214 may be positioned on the top surface 212 of the material 210. For example, in one embodiment, the glass material 214 may be bonded to the top surface 212 of the material 210. In another embodiment, the glass material 214 may be spun on the top surface 212 of the material 210. Generally, in conventional approaches to creating a wave guide, refractive index matching between the glass material 214 and the material 210 is unattainable due to conventional approaches that use a soft resin-like material as a stamp material. By utilizing the master substrate 202 rather than a soft resin-like stamp material, the current approach is able to achieve a refractive index of the material 210 approaching, matching, and exceeding that of the glass material 214.

[0020] At block 110, the master substrate 202 is removed from the material 210. In one embodiment, the master substrate 202 may be removed from the

material 210 through a wet etch process. For example, the master substrate 202 may be removed from the material 210 using KOH to selectively etch away silicon comprising the master substrate 202 from the material 210. In another example, the master substrate 202 may be removed from the material 210 using a dry etch process.

[0021] After removal of the master substrate 202, a wave guide 230 remains. The wave guide 230 includes the glass material 214 with the material 210 deposited thereon. The material 210 includes a pattern 222 formed therein as a result of the projections 208 and trenches 209 of the inverse master substrate 202. Accordingly, the wave guide 230 includes a high refractive index material 210, which was previously unobtainable using conventional methods. The pattern 222 includes projections 231 formed between the projections 208 of the inverse master substrate 202. When the projections 208 are removed, trenches 233 are left between the projections 231. Accordingly, the pattern 222 is complementary to the pattern 204.

[0022] Figure 3 is a flow diagram that illustrates one embodiment of a method 300 for forming a wave guide, according to one embodiment. Figures 4A-4I illustrate cross-sectional views of a waveguide, according to one embodiment.

[0023] Figure 4A illustrates a cross-sectional view of a master substrate 402, according to one embodiment. The master substrate 402 may be formed from a silicon material. At block 302, a pattern 406 is formed on a surface of the master substrate 402, as illustrated in Figure 4B. In the embodiment shown, the master substrate 402 has the pattern 406 formed in a top surface 404 of the master substrate 402. The pattern 406 may be etched into the master substrate 402 using an etch process. The etch process forms the pattern 406 in the master substrate 402 such that an inverse master substrate is formed. The inverse master substrate 402 is such that the master substrate 402 includes a plurality of projections 407 protruding from the master substrate 402.

[0024] At block 304, a stamp material 408 is deposited on the top surface 404 of the master substrate 402, as shown in Figure 4C. For example, in one embodiment the stamp material 408 may be a soft material, such as silicone. At

block 306, the stamp material 408 is removed from the master substrate 402, as shown in Figure 4D. The stamp material 408 is removed from the master substrate 402, while keeping the structure of the master substrate 402 in place for subsequent use. A reverse pattern 410 is formed in the stamp material 408 as a result of the projections 407 of the master substrate 402.

[0025] At block 308, a second material is deposited on the stamp material 408, as shown in Figure 4E. For example, the second material is deposited on the top surface 412 of the stamp material 408, and into the reverse pattern 410 formed in the second material. Such deposition creates a daughter substrate 414, which may be subsequently used to create a wave guide. In one embodiment, the second material may be a silicon based material, such as SiO_2, SiN, C, or the like. Generally, the second material may be any material that may be grown, spun onto, or deposited onto the stamp material 408, be rigid enough to act as a mold, be a scaffold for the high index material to be grown/deposited, and be able to be selectively etched away with respect to a high index material.

[0026] At block 310, the stamp material 408 is removed from the daughter substrate 414, as shown in Figure 4F. Removal of the stamp material 408 from the daughter substrate 414 exposes an inverse pattern 417 of projections 416 extending from a top surface 415 of the daughter substrate 414. The inverse pattern 417 is equivalent to the pattern 406 in the master substrate 402. Accordingly, the daughter substrate 414 is a disposable version of the master substrate 402, while the master substrate 402 may be repeatedly used to create subsequent daughter substrates.

[0027] At block 312, a material 418 is formed on a top surface of the daughter substrate 414, as shown in Figure 4G. For example, a high refractive index (high-n) material is grown on the top surface 415 of the daughter substrate 414. In another example, a high refractive index (high-n) material is conformally deposited on the top surface 415 of the daughter substrate 414. In some embodiments, the high-n material may be formed from an oxide, such as, for example, MoO_3, TiO_2, SiO, SiON, and the like. Generally, the material 418 index may have a refractive index of greater than 1.55. In some embodiments,

the material 418 may have a refractive index substantially equal to that of glass (e.g., n ≈ 1.4-1.8). In other embodiments, the material 418 may have a refractive index substantially greater than glass (e.g., n > 1.7).

[0028] At block 314, the material 418 may, optionally, undergo a chemical mechanical polishing (CMP) process, as shown in Figure 4H. For example, the daughter substrate 414 may undergo a CMP process to planarize a top surface 421 of the material 418. Planarizing the top surface 421 of the material 418 may allow for a more robust bonding to other components of the waveguide.

[0029] At block 316, a glass material 420 may be positioned on the top surface 421 of the material 418, as shown in Figure 4H. For example, in one embodiment, the glass material 420 may bond to the top surface 421 of the material 418. In another embodiment, the glass material 420 may be spun onto the top surface 421 of the material 418. Generally, in conventional approaches to creating wave guide, a refractive index matching between the glass material 420 and the material 418 is unattainable due to conventional approaches using a soft resin-like material as a stamp material. By utilizing the daughter substrate 414 rather than a soft resin-like stamp material, the current approach is able to achieve a refractive index of the material 418 approaching, matching, and exceeding that of the glass material 420.

[0030] At block 318, the daughter substrate 414 is removed from the material 418, as shown in Figure 4I. In one embodiment, the daughter substrate 414 may be removed from the material 418 through a wet etch process. For example, the daughter substrate 414 may be removed from the material 418 using KOH to selectively etch away silicon comprising the daughter substrate 414 from the material 418. In another example, the daughter substrate 414 may be removed from the material 418 using a dry etch process.

[0031] After removal of the daughter substrate 414, a wave guide 424 remains. The wave guide 424 includes the glass material 420 with the material 418 deposited thereon. The material 418 includes a pattern 422 formed therein as a result of the projections 416 and trenches 419 of the daughter substrate 414. Accordingly, the wave guide 424 includes a high refractive index material 418,

which was previously unobtainable using conventional methods. The pattern 422 includes projections 431 formed between the projections 407 of the inverse master substrate 402. When the projections 416 are removed, trenches 433 are left between the projections 431. Accordingly, the pattern 422 is complementary to the pattern 417.

[0032] At decision 320, it is determined whether an additional wave guide may be made. If an additional wave guide is desired, the method 300 reverts to block 304 for creation of a subsequent daughter substrate. If, however, an additional wave guide is not desired, the method 300 ends.

[0033] While the foregoing is directed to embodiments of the present invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

Claims

What is claimed is:

1. A method of forming a wave guide, comprising:

forming an inverse substrate having a plurality of projections and trenches extending therefrom;

forming a high refractive index material on a top surface of the inverse substrate;

positioning a glass layer on a top surface of the high refractive index material; and

removing the inverse substrate from the high refractive index material.

2. The method of claim 1, wherein the forming the inverse substrate, comprises etching a silicon layer.

3. The method of claim 1, wherein the high refractive index material has a refractive index of at least 1.4.

4. The method of claim 3, wherein the high refractive index material has a refractive index of about 1.55 to about 1.8.

5. The method of claim 1, wherein the removing the inverse substrate from the high refractive index material, comprises performing a wet etch process on the inverse master substrate.

6. The method of claim 1, where the removing the inverse substrate from the high refractive index material, comprises performing a dry etch process on the inverse master substrate.

7. The method of claim 1, wherein the forming the high refractive index material on a top surface of the inverse substrate, comprises conformally

depositing the high refractive index material on the top surface of the inverse substrate.

8. The method of claim 1, wherein the forming the high refractive index material on a top surface of the inverse substrate, comprises growing the high refractive index material on the top surface of the inverse substrate.

9. A method of forming a wave guide, comprising:

forming an inverse daughter substrate having a pattern of a plurality of projections and trenches formed on a surface thereof, comprising:

forming an inverse master substrate having a pattern of a plurality of projections extending therefrom formed on a surface thereof, wherein the pattern of the inverse master substrate is substantially equal to the pattern of the inverse daughter substrate;

forming a high refractive index material on a top surface of the inverse daughter substrate; and

positioning a glass layer on a top surface of the high refractive index material; and

removing the inverse daughter substrate from the high refractive index material, leaving another plurality of projections and trenches in the high refractive index material that is complementary to the plurality of projections and trenches of the inverse daughter substrate.

10. The method of claim 9, wherein the forming an inverse daughter substrate having a pattern of a plurality of projections extending therefrom, further comprises:

depositing a stamp material on a top surface of the inverse master substrate and forming a pattern in the stamp material;

forming a layer on top of the stamp material and into the pattern formed in the stamp material; and

removing the stamp material from the silicon layer to form the inverse daughter substrate.

11. The method of claim 9, wherein the high refractive index material has a refractive index of at least 1.4 to about 1.8.

12. The method of claim 9, wherein the forming a high refractive index material on a top surface of the inverse daughter substrate, comprises conformally depositing the high refractive index material on the top surface of the inverse daughter substrate.

13. The method of claim 9, wherein the forming a high refractive index material on a top surface of the inverse daughter substrate, comprises growing the high refractive index material on the top surface of the inverse daughter substrate.

14. The method of claim 9, further comprising:

forming a second inverse daughter substrate having a second pattern of a second plurality of projections extending therefrom, comprising:

depositing a second stamp material on a second top surface of the inverse master substrate and forming a second pattern in the stamp material;

depositing a second layer on top of the second stamp material and into the second pattern formed in the second stamp material; and

removing the second stamp material from the second layer to form the second inverse daughter substrate, wherein the second pattern of the second plurality of projections is substantially equivalent to the pattern of the inverse master substrate.

15. The method of claim 14, further comprising:

forming a second high-refractive index material on a top surface of the second inverse daughter substrate;

positioning a second glass layer on a top surface of the second high-refractive index material; and

removing the second inverse daughter substrate from the second high refractive index material to form a second wave guide.

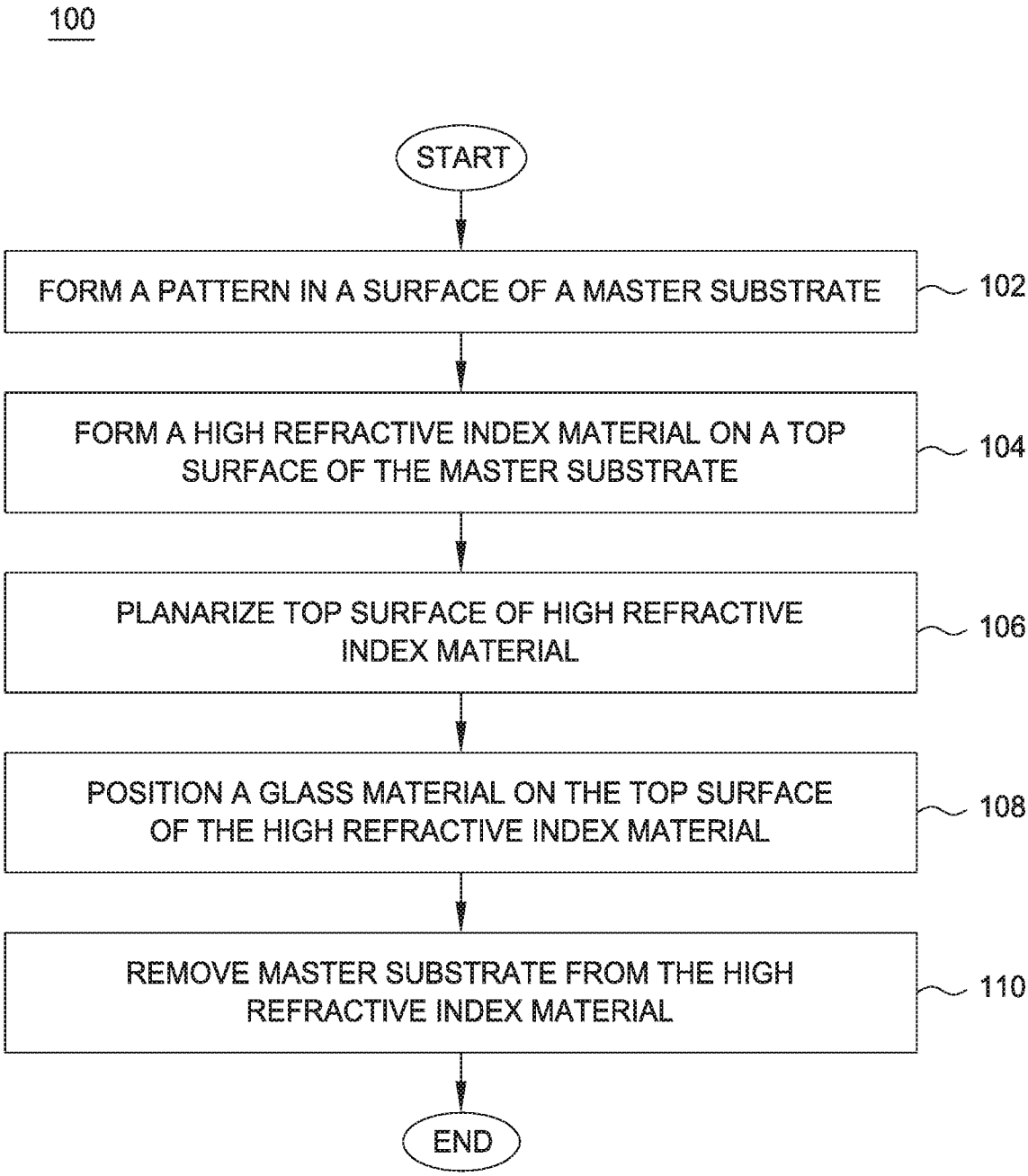

100
START
FORM A PATTERN IN A SURFACE OF A MASTER SUBSTRATE
102
FORM A HIGH REFRACTIVE INDEX MATERIAL ON A TOP SURFACE OF THE MASTER SUBSTRATE
104
PLANARIZE TOP SURFACE OF HIGH REFRACTIVE INDEX MATERIAL
106
POSITION A GLASS MATERIAL ON THE TOP SURFACE OF THE HIGH REFRACTIVE INDEX MATERIAL
108
REMOVE MASTER SUBSTRATE FROM THE HIGH REFRACTIVE INDEX MATERIAL
110
END

FIG. 1

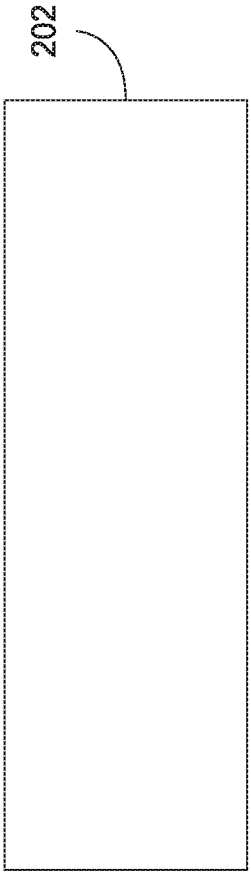


FIG. 2A

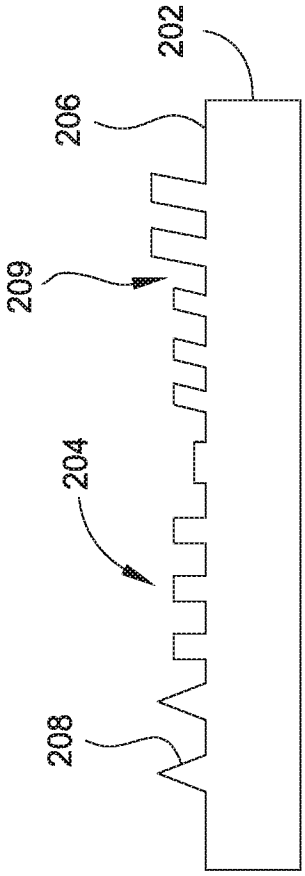


FIG. 2B

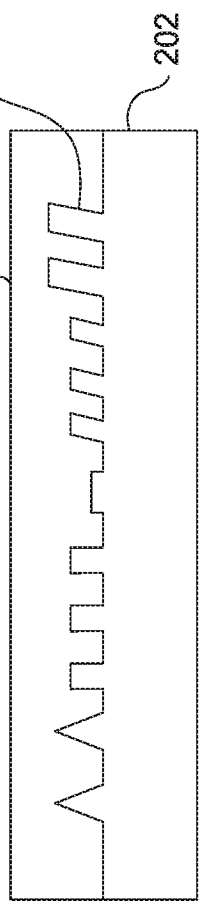


FIG. 2C

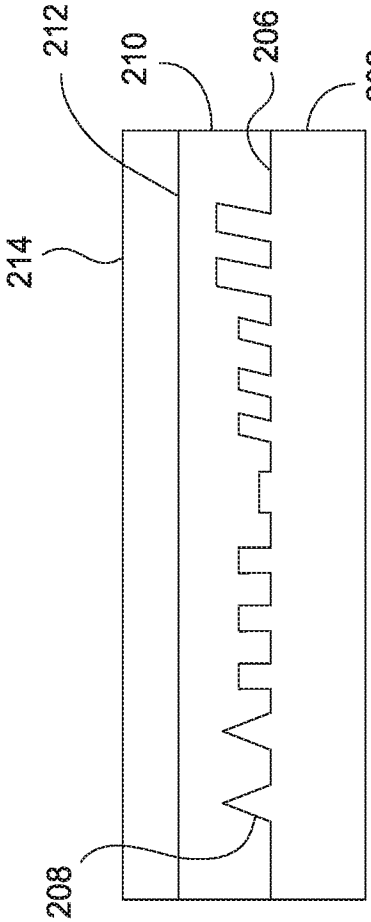


FIG. 2D

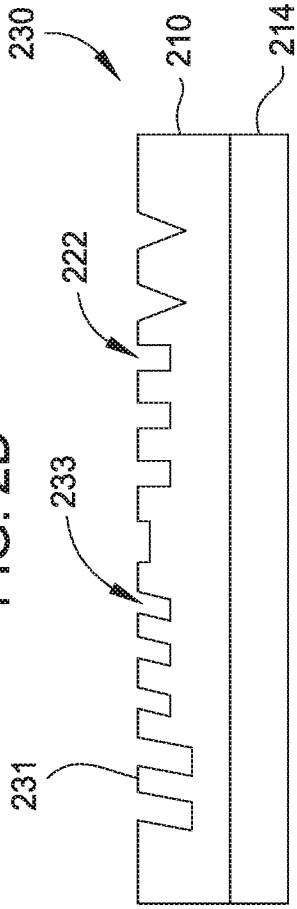


FIG. 2E

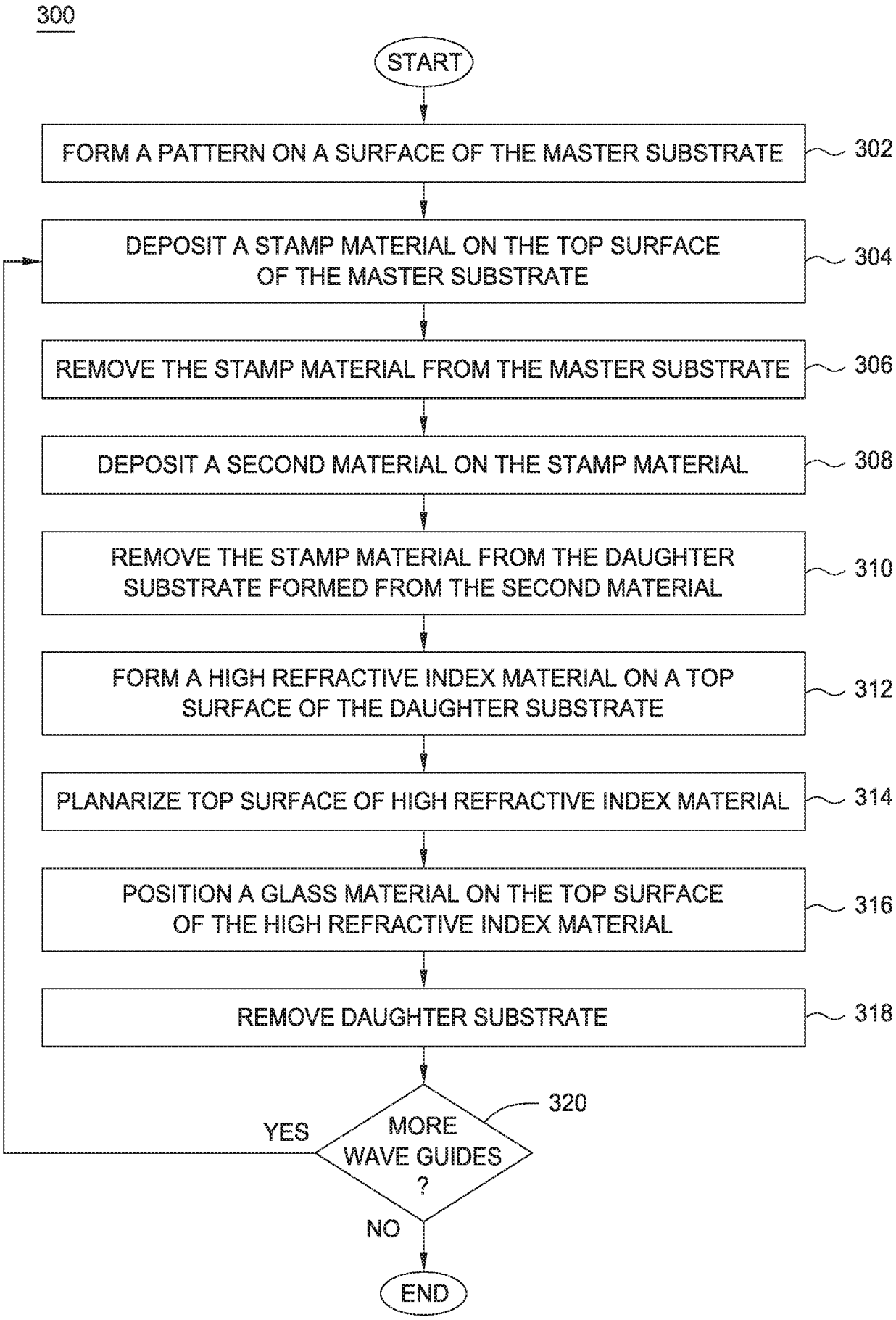

300
START
FORM A PATTERN ON A SURFACE OF THE MASTER SUBSTRATE
302
DEPOSIT A STAMP MATERIAL ON THE TOP SURFACE OF THE MASTER SUBSTRATE
304
REMOVE THE STAMP MATERIAL FROM THE MASTER SUBSTRATE
306
DEPOSIT A SECOND MATERIAL ON THE STAMP MATERIAL
308
REMOVE THE STAMP MATERIAL FROM THE DAUGHTER SUBSTRATE FORMED FROM THE SECOND MATERIAL
310
FORM A HIGH REFRACTIVE INDEX MATERIAL ON A TOP SURFACE OF THE DAUGHTER SUBSTRATE
312
PLANARIZE TOP SURFACE OF HIGH REFRACTIVE INDEX MATERIAL
314
POSITION A GLASS MATERIAL ON THE TOP SURFACE OF THE HIGH REFRACTIVE INDEX MATERIAL
316
REMOVE DAUGHTER SUBSTRATE
318
MORE WAVE GUIDES ?
320
YES
NO
END

FIG. 3

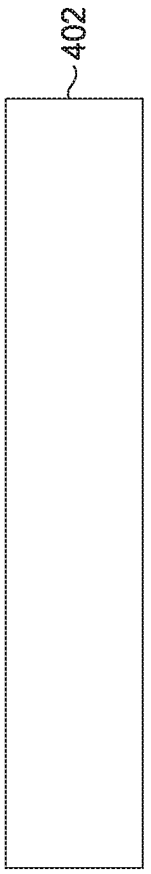


FIG. 4A

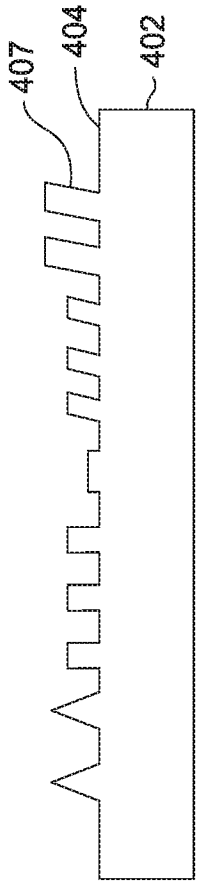


FIG. 4B

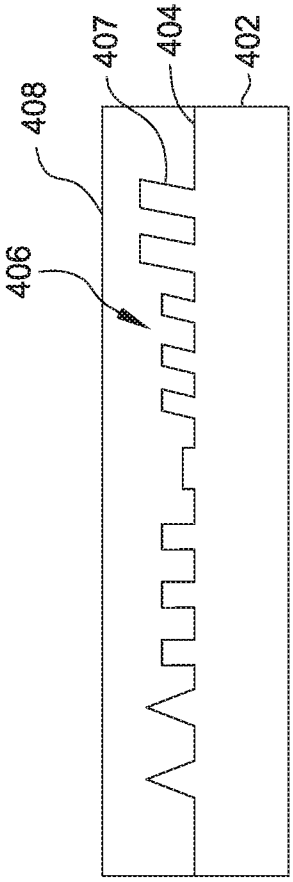


FIG. 4C

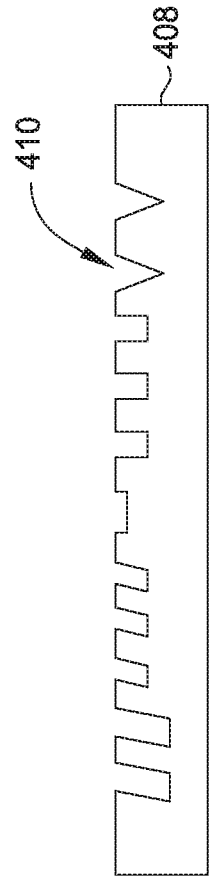


FIG. 4D

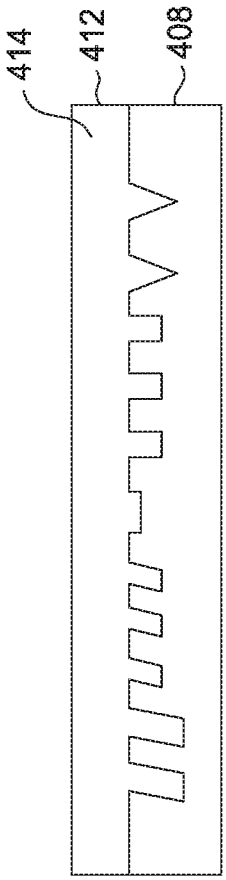


FIG. 4E

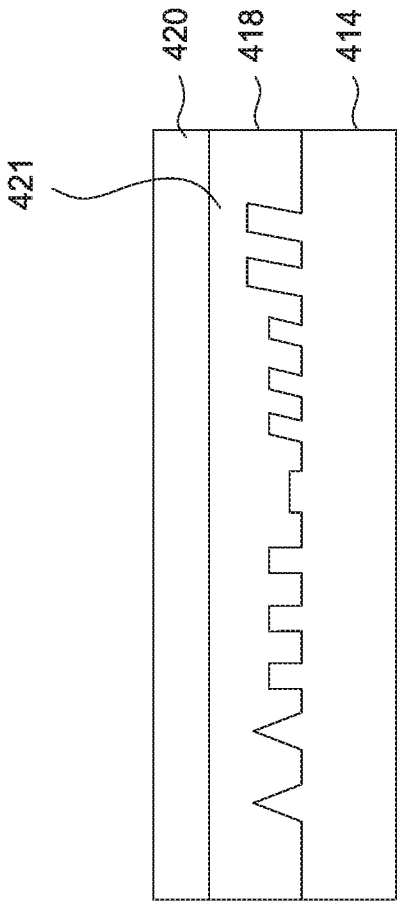


FIG. 4H

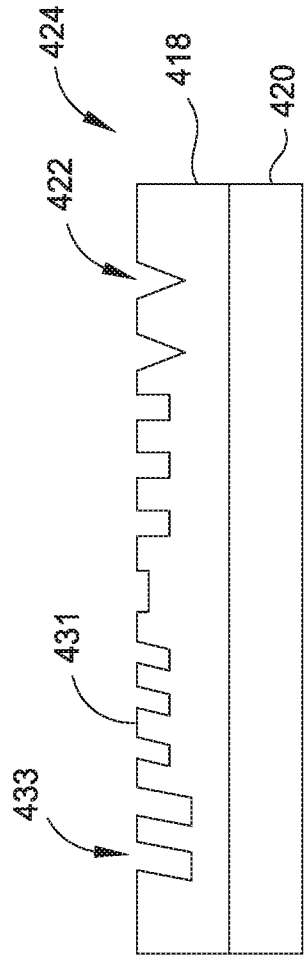


FIG. 4I

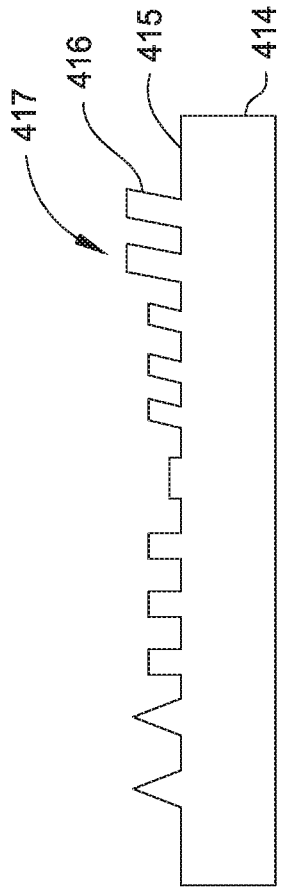


FIG. 4F

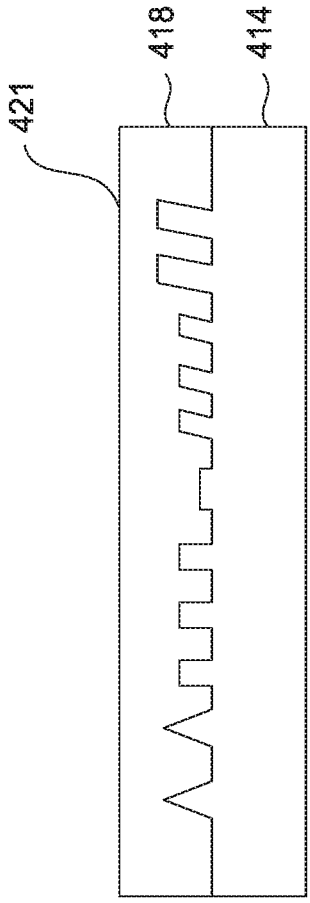


FIG. 4G

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2018/041688

A. CLASSIFICATION OF SUBJECT MATTER

G03F 7/20(2006.01)i, G03F 1/80(2012.01)i, G03F 7/00(2006.01)i, H01L 21/027(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)
G03F 7/20; B05D 1/18; B29C 35/08; B29C 59/02; B29C 71/04; B32B 38/06; C03B 37/022; C09D 163/00; G03F 1/80; G03F 7/00; H01L 21/027

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: wave guide, refractive index, glass layer, master, pattern

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2015-0322286 A1 (THE REGENTS OF THE UNIVERSITY OF CALIFORNIA) 12 November 2015 See paragraphs [0025]-[0075] and figures 1-10.	1-15
Y	US 2010-0006211 A1 (MARTIN B WOLK et al.) 14 January 2010 See paragraphs [0026]-[0041] and figures 1-8c.	1-15
Y	US 2006-0279025 A1 (BABAK HEIDARI et al.) 14 December 2006 See paragraphs [0107]-[0118] and figure 1.	9-15
A	US 2012-0175822 A1 (TAKATO INAMIYA et al.) 12 July 2012 See paragraphs [0104]-[0108] and figures 1-3.	1-15
A	US 5858051 A (YOSHIZO KOMIYAMA et al.) 12 January 1999 See column 5, line 45 - column 12, line 65 and figures 2-11K.	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	Date of mailing of the international search report
30 November 2018 (30.11.2018)	**30 November 2018 (30.11.2018)**

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2018/041688

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