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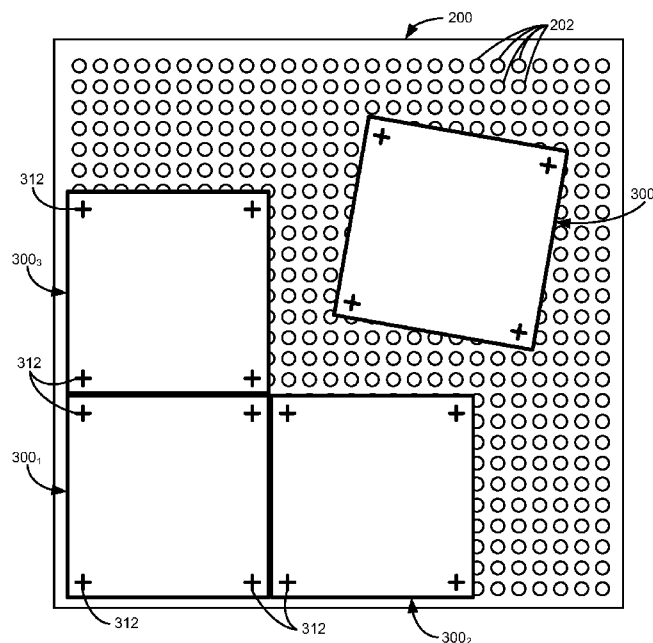


FIG. 3A

(57) Abstract: A sub-display for a tiled display includes a backplane and an array of light sources. The backplane comprises a first surface, a second surface opposite to the first surface, and an edge surface extending between the first surface and the second surface. The array of light sources is coupled to the first surface. The backplane comprises a plurality of alignment marks. Each alignment mark is configured to emit light when the sub-display is illuminated through the edge surface.



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SUB-DISPLAYS AND METHODS FOR FABRICATING TILED DISPLAYS FROM SUB-DISPLAYS

BACKGROUND

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of priority under 35 U.S.C. § 119 of U.S. Provisional Application Serial No. 62/588,608 filed on November 20, 2017, the content of which is relied upon and incorporated herein by reference in its entirety.

Field

[0002] The present disclosure relates generally to tiled displays. More particularly, it relates to tiled displays comprising alignment marks and methods for fabricating tiled displays.

Technical Background

[0003] Large-area displays may not be practical to manufacture on a single large-area substrate. For example, the size of the display may be larger than what existing processing equipment can handle and/or the yield of large display sizes may be much lower than the yield of smaller display sizes. In these cases, manufacturing a display by tiling multiple smaller sub-displays is advantageous. The tiling of smaller sub-displays to create larger displays may apply to display technologies including light emitting diode (LED), microLED, organic light emitting diode (OLED), and liquid crystal display (LCD). A common problem of tiled displays is the alignment of the sub-displays of the tiled display.

[0004] MicroLEDs are small (e.g., typically less than 100 μ m by 100 μ m) light emitting components. They are inorganic semiconductor components producing high luminance up to 50 million nits. Therefore, microLEDs are particularly suitable for high resolution and large tiled displays. However, sub-displays of a tiled microLED display should be precisely aligned to prevent visible seams between the sub-displays under expected viewing conditions.

Accordingly, sub-displays and tiled displays fabricated from the sub-displays that can be precisely aligned are disclosed herein.

SUMMARY

[0005] Some embodiments of the present disclosure relate to a sub-display for a tiled display. The sub-display includes a backplane and an array of light sources. The backplane comprises a first surface, a second surface opposite to the first surface, and an edge surface extending between the first surface and the second surface. The array of light sources is coupled to the first surface. The backplane comprises a plurality of alignment marks. Each alignment mark is configured to emit light when the sub-display is illuminated through the edge surface.

[0006] Yet other embodiments of the present disclosure relate to a method for fabricating a display. The method includes placing a plurality of sub-displays on a fixture comprising an array of vacuum holes at a first vacuum level for holding each of the plurality of sub-displays. The method includes aligning the plurality of sub-displays to each other by sliding each sub-display on the fixture. The method includes increasing the vacuum level of the vacuum holes to a second vacuum level such that each of the plurality of sub-displays are immovable. The method includes attaching a base plate to the plurality of sub-displays.

[0007] Yet other embodiments of the present disclosure relate to a method for fabricating a display. The method includes placing a first sub-display on a fixture and laser welding the first sub-display to the fixture. The method includes placing a second sub-display on the fixture and aligning the second sub-display with the first sub-display. The method includes laser welding the second sub-display to the fixture.

[0008] The sub-displays and methods for fabricating tiled displays from the sub-displays disclosed herein enable precise alignment between the sub-displays during the assembly of the tiled displays. By precisely aligning the sub-displays, visible seams between the tiled sub-displays may be minimized or effectively eliminated under expected viewing conditions.

[0009] Additional features and advantages will be set forth in the detailed description which follows, and in part will be readily apparent to those skilled in the art from that description or recognized by practicing the embodiments described herein, including the detailed description which follows, the claims, as well as the appended drawings.

[0010] It is to be understood that both the foregoing general description and the following detailed description describe various embodiments and are intended to provide an overview

or framework for understanding the nature and character of the claimed subject matter. The accompanying drawings are included to provide a further understanding of the various embodiments, and are incorporated into and constitute a part of this specification. The drawings illustrate various embodiments described herein, and together with the description serve to explain the principles and operations of the claimed subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

- [0011] FIGS. 1A-1B schematically depict one example of a sub-display;
- [0012] FIGS. 2A-2B schematically depict one example of a vacuum fixture;
- [0013] FIGS. 3A-4B schematically depict one example of an assembly of a tiled display;
- [0014] FIGS. 5A-6C schematically depict another example of an assembly of a tiled display;
- [0015] FIGS. 7A-7B schematically depict yet another example of an assembly of a tiled display;
- [0016] FIGS. 8A-8B schematically depict yet another example of an assembly of a tiled display;
- [0017] FIG. 9 is a flow diagram illustrating one example of a method for fabricating a display; and
- [0018] FIG. 10 is a flow diagram illustrating another example of a method for fabricating a display.

DETAILED DESCRIPTION

[0019] Reference will now be made in detail to embodiments of the present disclosure, examples of which are illustrated in the accompanying drawings. Whenever possible, the same reference numerals will be used throughout the drawings to refer to the same or like parts. However, this disclosure may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein.

[0020] Ranges can be expressed herein as from “about” one particular value, and/or to “about” another particular value. When such a range is expressed, another embodiment includes from the one particular value and/or to the other particular value. Similarly, when values are expressed as approximations, by use of the antecedent “about,” it will be understood that the particular value forms another embodiment. It will be further understood

that the endpoints of each of the ranges are significant both in relation to the other endpoint, and independently of the other endpoint.

[0021] Directional terms as used herein - for example up, down, right, left, front, back, top, bottom, vertical, horizontal - are made only with reference to the figures as drawn and are not intended to imply absolute orientation.

[0022] Unless otherwise expressly stated, it is in no way intended that any method set forth herein be construed as requiring that its steps be performed in a specific order, nor that with any apparatus, specific orientations be required. Accordingly, where a method claim does not actually recite an order to be followed by its steps, or that any apparatus claim does not actually recite an order or orientation to individual components, or it is not otherwise specifically stated in the claims or description that the steps are to be limited to a specific order, or that a specific order or orientation to components of an apparatus is not recited, it is in no way intended that an order or orientation be inferred, in any respect. This holds for any possible non-express basis for interpretation, including: matters of logic with respect to arrangement of steps, operational flow, order of components, or orientation of components; plain meaning derived from grammatical organization or punctuation, and; the number or type of embodiments described in the specification.

[0023] As used herein, the singular forms "a," "an," and "the" include plural references unless the context clearly dictates otherwise. Thus, for example, reference to "a" component includes aspects having two or more such components, unless the context clearly indicates otherwise.

[0024] Referring now to FIGS. 1A-1B, an exemplary sub-display 100 is schematically depicted. FIG. 1A is a top view of sub-display 100 and FIG. 1B is a side view of sub-display 100. Sub-display 100 includes a backplane 102 and an array of light sources 110. Backplane 102 includes a first surface 104, a second surface 106 opposite to the first surface 104, and an edge surface 108 extending between the first surface 104 and the second surface 106. While backplane 102 is square shaped in FIG. 1A, in other examples backplane 102 may have another suitable shape, such as a rectangular, hexagonal, or other polygonal shape.

[0025] Each light source 110 is coupled to the first surface 104 of backplane 102. Light sources 110 may be arranged in any suitable numbers of rows and columns. Each light source 110 may include a light emitting diode (LED), a microLED, an organic light emitting diode (OLED), or another suitable light source. Each light source 110 is electrically coupled to circuitry (not shown) on backplane 102 for controlling the operation of each light source. In

certain exemplary embodiments, backplane 102 includes a glass substrate with an array of thin film transistors (TFTs) formed thereon, where each TFT is electrically coupled to a light source 110. Sub-display 100 may also include additional components (not shown) over light sources 110, such as a common electrode for light sources 110, color filters, and/or cover glass.

[0026] Backplane 102 includes a plurality of alignment marks 112 for aligning the sub-display 100 with a further sub-display or further sub-displays when fabricating a tiled display with sub-display 100. Each alignment mark 112 is configured to emit light (e.g., through first surface 104 and/or second surface 106) when sub-display 100 is illuminated through the edge surface 108. While one edge surface 108 is identified in FIG. 1B, any edge surface extending between first surface 104 and second surface 106 of backplane 102 may be illuminated to cause each alignment mark 112 to emit light. Alignment marks 112 do not substantially alter the optical properties of sub-display 100 under expected viewing conditions.

[0027] In certain exemplary embodiments, backplane 102 includes a glass substrate and each alignment mark 112 comprises a defect in the glass. The defects in the glass may, for example, be created using a laser beam directed at the glass substrate to heat the glass to disrupt the crystalline structure within the glass. In this example, backplane 102 includes four alignment marks 112, and each alignment mark is arranged in a corner of backplane 102. In other examples, backplane 102 may include any suitable number of alignment marks 112, and each alignment mark may be arranged at any suitable location within backplane 102. Each alignment mark 112 has a cross shape in backplane 102. In other examples, however, each alignment mark 112 may have another suitable shape, such as a dot, line, square, etc.

[0028] Each alignment mark 112 may be visible by a machine vision system (e.g., a system including an imaging device to detect the position and orientation of each alignment mark 112 and a robotic device that is controlled based on information received from the imaging device). In this case, to fabricate a tiled display using a plurality of sub-displays 100, edge 108 of a first sub-display 100 may be illuminated such that each alignment mark 112 emits light. The machine vision system records the exact position of first sub-display 100 based on the alignment marks 112. The machine vision system precisely picks up the first sub-display 100 and precisely places the first sub-display 100 on a fixture for assembling a tiled display. The machine vision system then repeats the process to align a second sub-display 100 with the first sub-display 100. The process may be repeated until the desired number of sub-

displays 100 have been precisely aligned with each other. A base plate may then be attached to the aligned sub-displays to complete fabrication of the tiled display.

[0029] FIGS. 2A-2B schematically depict an exemplary vacuum fixture 200. FIG. 2A is a top view of vacuum fixture 200 and FIG. 2B is a sectional view of vacuum fixture 200. Vacuum fixture 200 includes an array of vacuum holes 202 and a vacuum 204 for applying a vacuum to vacuum holes 202. Vacuum holes 202 may be arranged in any suitable numbers of rows and columns. In this example, vacuum fixture 200 is square shaped, and each vacuum hole 202 is circular in shape. In other examples, vacuum fixture 200 may have another suitable shape, such as rectangular, and each vacuum hole 202 may have another suitable shape, such as rectangular, hexagonal, or other polygonal.

[0030] Vacuum fixture 200 may, for example, be used to fabricate a tiled display from a plurality of sub-displays, such as sub-displays 100 previously described and illustrated with reference to FIGS. 1A-1B. The spacing between vacuum holes 202 may be set such that each sub-display is held by a plurality of vacuum holes 202. The size of vacuum fixture 200 may be selected to accommodate the largest tiled display to be fabricated using the vacuum fixture. For smaller tiled displays, a portion of vacuum holes 202 that are not used to hold a sub-display may be covered (e.g., via a sheet of paper, cardboard, metal, etc.) to adjust the vacuum level applied to the vacuum holes 202 that are used to hold a sub-display. Vacuum 204 may also be adjusted to change the vacuum level applied to vacuum holes 202.

[0031] FIGS. 3A-4B schematically depict an exemplary embodiment of an assembly of a tiled display using vacuum fixture 200 of FIGS. 2A-2B. FIG. 3A is a top view and FIG. 3B is a sectional view illustrating the alignment of a plurality of sub-displays 300₁ to 300₄ on vacuum fixture 200. While four sub-displays are used in this example to assemble a tiled display including two rows and two columns, in other examples any suitable number of sub-displays may be used to assemble a tiled display having any suitable numbers of rows and/or columns. Each sub-display 300₁ to 300₄ may, for example, be a sub-display 100 as previously described and illustrated with reference to FIGS. 1A-1B. Each sub-display 300₁ to 300₄ may include alignment marks 312, such as alignment marks 112 of FIGS. 1A-1B. FIG. 3A illustrates a first sub-display 300₁, a second sub-display 300₂, and a third sub-display 300₃ aligned with each other while a fourth sub-display 300₄ is yet to be aligned with the first sub-display 300₁, the second sub-display 300₂, and the third sub-display 300₃. Sub-displays 300₁ to 300₄ may, for example, be placed on vacuum fixture 200 with the array of light sources of each sub-display facing vacuum fixture 200.

[0032] Prior to fabricating a tiled display, vacuum 204 may be adjusted to a first vacuum level. The first vacuum level is suitable for partially restricting the motion of sub-displays 300₁ to 300₄ on vacuum fixture 200. The first vacuum level holds sub-displays 300₁ to 300₄ on vacuum fixture 200 while still allowing movement (i.e., sliding) of the sub-displays by applying a sufficient force to the sub-displays. In certain exemplary embodiments, the first vacuum level may be between about 80 mBar and 120 mBar.

[0033] A first sub-display 300₁ may be placed on vacuum fixture 200 and slid to a desired position (e.g., the lower left corner of vacuum fixture 200 in this example). A second sub-display 300₂ may be placed on vacuum fixture 200 and slid on vacuum fixture 200 to align second sub-display 300₂ with first sub-display 300₁. Second sub-display 300₂ may, for example, be aligned with first sub-display 300₁ by aligning the alignment marks 312 of second sub-display 300₂ with the corresponding alignment marks 312 of first sub-display 300₁. A third sub-display 300₃ may be placed on vacuum fixture 200 and slid on vacuum fixture 200 to align third sub-display 300₃ with first sub-display 300₁ and/or second sub-display 300₂. Third sub-display 300₃ may, for example, be aligned with first sub-display 300₁ by aligning the alignment marks 312 of third sub-display 300₃ with the corresponding alignment marks 312 of first sub-display 300₁. Likewise, a fourth sub-display 300₄ may be placed on vacuum fixture 200 and may be slid on vacuum fixture 200 to align fourth sub-display 300₄ with first sub-display 300₁, second sub-display 300₂, and/or third sub-display 300₃. The alignment of sub-displays 300₁ to 300₄ may be implemented manually by a human assembler, automatically by a machine vision system, or by a combination thereof (e.g., the human assembler coarsely aligns sub-displays 300₁ to 300₄ with each other and the machine vision system finely aligns sub-displays 300₁ to 300₄ with each other).

[0034] FIG. 4A is a top view and FIG. 4B is a sectional view of an exemplary tiled display 314 after attaching a base plate 316 to aligned sub-displays 300₁ to 300₄ on vacuum fixture 200. After aligning sub-displays 300₁ to 300₄ as described with reference to FIGS. 3A-3B and prior to attaching base plate 316, vacuum 204 may be increased to a second vacuum level greater than the first vacuum level. The second vacuum level is suitable for completely restricting the motion of sub-displays 300₁ to 300₄ on vacuum fixture 200 such that the sub-displays are immovable (i.e., the force applied to the sub-displays to align the sub-displays at the first vacuum level is no longer sufficient to move the sub-displays). In certain exemplary embodiments, the second vacuum level may be above a level between about 200 mBar and

300 mBar. The second vacuum level may also ensure that sub-displays 300₁ to 300₄ lie in the same plane.

[0035] With sub-displays 300₁ to 300₄ immovable due to the second vacuum level, base plate 316 may be aligned with and attached to sub-displays 300₁ to 300₄. Base plate 316 may, for example, include circuitry for routing power and signals to each sub-display 300₁ to 300₄ to control the operation of each light source of each sub-display 300₁ to 300₄. In certain exemplary embodiments, alignment marks 312 may be used to align base plate 316 with sub-displays 300₁ to 300₄. Base plate 316 may, for example, be attached to sub-displays 300₁ to 300₄ using fasteners and/or an adhesive material. After attaching base plate 316 to complete tiled display 314, the vacuum may be released and tiled display 314 may be removed from vacuum fixture 200.

[0036] FIGS. 5A-6C schematically depict another example of an assembly of a tiled display. FIG. 5A is a top view and FIG. 5B is a side view illustrating the alignment of a plurality of sub-displays 300₁ to 300₄ on a fixture 400. Each sub-display 300₁ to 300₄ may, for example, be a sub-display 100 as previously described and illustrated with reference to FIGS. 1A-1B. Each sub-display 300₁ to 300₄ may include alignment marks 312, such as alignment marks 112 of FIGS. 1A-1B. FIG. 5A illustrates a first sub-display 300₁, a second sub-display 300₂, and a third sub-display 300₃ aligned with each other while a fourth sub-display 300₄ is yet to be aligned with the first sub-display 300₁, the second sub-display 300₂, and the third sub-display 300₃. Sub-displays 300₁ to 300₄ may, for example, be placed on fixture 400 with the array of light sources of each sub-display facing fixture 400.

[0037] In certain exemplary embodiments, fixture 400 includes glass. A first sub-display 300₁ may be placed on fixture 400 and slid to a desired position (e.g., the lower left corner of fixture 400 in this example). The first sub-display 300₁ may then be laser welded to fixture 400 at a plurality of points to prevent movement of first sub-display 300₁. In this example, first sub-display 300₁ is laser welded to fixture 400 at four points 320 centered along the edges of first sub-display 300₁. In other examples, first sub-display 300₁ may be laser welded to fixture 400 using any suitable number of points arranged at any suitable location of first sub-display 300₁.

[0038] A sub-display may be laser welded to fixture 400 by focusing a laser beam at or near the interface between the sub-display and fixture 400. The laser beam melts the surface of the backplane of the sub-display and/or the surface of fixture 400 such that the sub-display adheres to fixture 400. The parameters (e.g., spot size, wavelength, power, repetition rate) of

the laser welding may be selected to create a permanent weld or a temporary weld between the sub-display and fixture 400. A permanent weld includes a stronger weld that if broken would damage the sub-display to at least an extent to which the optical properties of the sub-display are altered under expected viewing conditions. A temporary weld includes a weaker weld that if broken does not damage the sub-display and does not alter the optical properties of the sub-display under expected viewing conditions.

[0039] A second sub-display 300₂ may be placed on fixture 400 and slid on fixture 400 to align second sub-display 300₂ with first sub-display 300₁. Second sub-display 300₂ may, for example, be aligned with first sub-display 300₁ by aligning the alignment marks 312 of second sub-display 300₂ with the corresponding alignment marks 312 of first sub-display 300₁. The second sub-display 300₂ may then be laser welded to fixture 400 at a plurality of points 320 of second sub-display 300₂ to prevent movement of second sub-display 300₂. A third sub-display 300₃ may be placed on fixture 400 and slid on fixture 400 to align third sub-display 300₃ with first sub-display 300₁ and/or second sub-display 300₂. Third sub-display 300₃ may, for example, be aligned with first sub-display 300₁ by aligning the alignment marks 312 of third sub-display 300₃ with the corresponding alignment marks 312 of first sub-display 300₁. The third sub-display 300₃ may then be laser welded to fixture 400 at a plurality of points 320 of third sub-display 300₃ to prevent movement of third sub-display 300₃. Likewise, a fourth sub-display 300₄ may be placed on fixture 400 and may be slid on fixture 400 to align fourth sub-display 300₄ with first sub-display 300₁, second sub-display 300₂, and/or third sub-display 300₃. The fourth sub-display 300₄ may then be laser welded to fixture 400 at a plurality of points of fourth sub-display 300₄ to prevent movement of fourth sub-display 300₄. The alignment of sub-displays 300₁ to 300₄ may be implemented manually by a human assembler, automatically by a machine vision system, or by a combination thereof (e.g., the human assembler coarsely aligns sub-displays 300₁ to 300₄ with each other and the machine vision system finely aligns sub-displays 300₁ to 300₄ with each other).

[0040] FIG. 6A is a top view and FIG. 6B is a side view of an exemplary tiled display 314 after attaching a base plate 316 to sub-displays 300₁ to 300₄ on fixture 400 of FIGS. 5A-5B. With sub-displays 300₁ to 300₄ immovable on fixture 400 due to the laser welds 320, base plate 316 may be aligned with and attached to sub-displays 300₁ to 300₄. In certain exemplary embodiments, alignment marks 312 may be used to align base plate 316 with sub-displays 300₁ to 300₄. Base plate 316 may, for example, be attached to sub-displays 300₁ to 300₄ using fasteners and/or an adhesive material. In this example, laser welds 320 are weak

temporary welds designed to be broken after the assembly of tiled display 314 is complete. As such, after attaching base plate 316 to complete assembly of tiled display 314, the laser welds 320 are broken to release tiled display 314 from fixture 400. FIG. 6C is a side view of tiled display 314 after releasing the tiled display from fixture 400 resulting in broken laser welds 321. Broken laser welds 321 do not alter the optical properties of tiled display 314 under expected viewing conditions.

[0041] FIGS. 7A-7B schematically depict yet another example of an assembly of a tiled display. FIG. 7A is a top view and FIG. 7B is a side view illustrating the alignment of a plurality of sub-displays 300₁ to 300₄ on a fixture 500. Each sub-display 300₁ to 300₄ may, for example, be a sub-display 100 as previously described and illustrated with reference to FIGS. 1A-1B. Each sub-display 300₁ to 300₄ may include alignment marks 312, such as alignment marks 112 of FIGS. 1A-1B. FIG. 7A illustrates a first sub-display 300₁, a second sub-display 300₂, and a third sub-display 300₃ aligned with each other while a fourth sub-display 300₄ is yet to be aligned with the first sub-display 300₁, the second sub-display 300₂, and the third sub-display 300₃. Sub-displays 300₁ to 300₄ may, for example, be placed on fixture 500 with the array of light sources of each sub-display either facing fixture 500 or facing away from fixture 500 depending upon the type of fixture 500.

[0042] In this example, fixture 500 becomes a part of the completed tiled display. In certain exemplary embodiments, fixture 500 includes a glass substrate. In this case, sub-displays 300₁ to 300₄ may be placed on fixture 500 with the array of light sources of each sub-display 300₁ to 300₄ facing fixture 500 and fixture 500 may become a cover glass layer of the tiled display. In another example, fixture 500 includes a base plate. In this case, sub-displays 300₁ to 300₄ may be placed on fixture 500 with the array of light sources of each sub-display 300₁ to 300₄ facing away from fixture 500.

[0043] A first sub-display 300₁ may be placed on fixture 500 and slid to a desired position (e.g., the lower left corner of fixture 500 in this example). The first sub-display 300₁ may then be laser welded to fixture 500 at a plurality of points to prevent movement of first sub-display 300₁. In this example, first sub-display 300₁ is laser welded to fixture 500 at four points 320 centered along the edges of first sub-display 300₁. In other examples, first sub-display 300₁ may be laser welded to fixture 500 using any suitable number of points arranged at any suitable location of first sub-display 300₁.

[0044] A second sub-display 300₂ may be placed on fixture 500 and slid on fixture 400 to align second sub-display 300₂ with first sub-display 300₁. Second sub-display 300₂ may, for

example, be aligned with first sub-display 300₁ by aligning the alignment marks 312 of second sub-display 300₂ with the corresponding alignment marks 312 of first sub-display 300₁. The second sub-display 300₂ may then be laser welded to fixture 500 at a plurality of points 320 of second sub-display 300₂ to prevent movement of second sub-display 300₂.

[0045] A third sub-display 300₃ may be placed on fixture 500 and slid on fixture 500 to align third sub-display 300₃ with first sub-display 300₁ and/or second sub-display 300₂. Third sub-display 300₃ may, for example, be aligned with first sub-display 300₁ by aligning the alignment marks 312 of third sub-display 300₃ with the corresponding alignment marks 312 of first sub-display 300₁. The third sub-display 300₃ may then be laser welded to fixture 500 at a plurality of points 320 of third sub-display 300₃ to prevent movement of third sub-display 300₃.

[0046] Likewise, a fourth sub-display 300₄ may be placed on fixture 500 and may be slid on fixture 500 to align fourth sub-display 300₄ with first sub-display 300₁, second sub-display 300₂, and/or third sub-display 300₃. The fourth sub-display 300₄ may then be laser welded to fixture 500 at a plurality of points 320 to prevent movement of fourth sub-display 300₄. The alignment of sub-displays 300₁ to 300₄ may be implemented manually by a human assembler, automatically by a machine vision system, or by a combination thereof (e.g., the human assembler coarsely aligns sub-displays 300₁ to 300₄ with each other and the machine vision system finely aligns sub-displays 300₁ to 300₄ with each other). In this example, laser welds 320 are strong permanent welds. Once sub-displays 300₁ to 300₄ are laser welded to fixture 500, the tiled display is complete and the fixture 500 becomes a part of the tiled display.

[0047] FIGS. 8A-8B schematically depict yet another example of an assembly of a tiled display. FIG. 8A is a top view and FIG. 8B is a side view illustrating the alignment of a plurality of sub-displays 300₁ to 300₄ on a fixture 600. Each sub-display 300₁ to 300₄ may, for example, be a sub-display 100 as previously described and illustrated with reference to FIGS. 1A-1B. Each sub-display 300₁ to 300₄ may include alignment marks 312, such as alignment marks 112 of FIGS. 1A-1B. FIG. 8A illustrates a first sub-display 300₁, a second sub-display 300₂, and a third sub-display 300₃ aligned with each other while a fourth sub-display 300₄ is yet to be aligned with the first sub-display 300₁, the second sub-display 300₂, and the third sub-display 300₃. Sub-displays 300₁ to 300₄ may, for example, be placed on fixture 500 with the array of light sources of each sub-display facing fixture 600.

[0048] Fixture 600 includes a metal frame 602 with standoffs 604. Each standoff 604 may have any suitable shape, such as circular, rectangular, hexagonal, etc. A first sub-display 300₁

may be placed on standoffs 604 of fixture 600 in a desired position (e.g., the lower left corner of fixture 600 in this example). The first sub-display 300₁ may then be laser welded to standoffs 604 of fixture 600 to create laser welds 320 to prevent movement of first sub-display 300₁. In this example, first sub-display 300₁ is laser welded to four standoffs 604 of fixture 600 centered along the edges of first sub-display 300₁. In other examples, first sub-display 300₁ may be laser welded to any suitable number of standoffs of fixture 600 arranged at any suitable location of first sub-display 300₁.

[0049] A second sub-display 300₂ may be placed on standoffs 604 of fixture 600 and aligned with first sub-display 300₁. Second sub-display 300₂ may, for example, be aligned with first sub-display 300₁ by aligning the alignment marks 312 of second sub-display 300₂ with the corresponding alignment marks 312 of first sub-display 300₁. The second sub-display 300₂ may then be laser welded to standoffs 604 of fixture 600 to create laser welds 320 to prevent movement of second sub-display 300₂. A third sub-display 300₃ may be placed on standoffs 604 of fixture 600 and aligned with first sub-display 300₁ and/or second sub-display 300₂. Third sub-display 300₃ may, for example, be aligned with first sub-display 300₁ by aligning the alignment marks 312 of third sub-display 300₃ with the corresponding alignment marks 312 of first sub-display 300₁. The third sub-display 300₃ may then be laser welded to standoffs 604 of fixture 600 to create laser welds 320 to prevent movement of third sub-display 300₃. Likewise, a fourth sub-display 300₄ may be placed on standoffs 604 of fixture 600 and aligned with first sub-display 300₁, second sub-display 300₂, and/or third sub-display 300₃. The fourth sub-display 300₄ may then be laser welded to standoffs 604 of fixture 600 to create laser welds 320 to prevent movement of fourth sub-display 300₄.

[0050] The alignment of sub-displays 300₁ to 300₄ may be implemented manually by a human assembler, automatically by a machine vision system, or by a combination thereof (e.g., the human assembler coarsely aligns sub-displays 300₁ to 300₄ with each other and the machine vision system finely aligns sub-displays 300₁ to 300₄ with each other). In this example, laser welds 320 are weak temporary welds. Once sub-displays 300₁ to 300₄ are laser welded to fixture 600, a base plate, such as base plate 316 as previously described and illustrated with reference to FIGS. 4A-4B may be attached to sub-displays 300₁ to 300₄ to complete assembly of the tiled display. Welds 320 may then be broken to release the tiled display from fixture 600. The released tiled display may be similar to tiled display 314 of FIG. 6C. In this example, fixture 600 may be reused to assemble other tiled displays.

[0051] FIG. 9 is a flow diagram illustrating an exemplary embodiment of a method 700 for fabricating a display. At 702, method 700 includes placing a plurality of sub-displays on a fixture comprising an array of vacuum holes at a first vacuum level for holding each of the plurality of sub-displays. The spacing between the vacuum holes in the array may be set such that each sub-display is held by a plurality of vacuum holes. Each sub-display of the plurality of sub-displays may include a backplane and an array of microLEDs coupled to the backplane.

[0052] At 704, method 700 includes aligning the plurality of sub-displays to each other by sliding each sub-display on the fixture. In certain exemplary embodiments, each of the plurality of sub-displays includes an alignment mark. In this case, aligning the plurality of sub-displays to each other includes aligning the alignment mark of each of the plurality of sub-displays with the alignment mark of another one of the plurality of sub-displays. At 706, method 700 includes increasing the vacuum level of the vacuum holes to a second vacuum level such that each of the plurality of sub-displays are immovable.

[0053] At 708, method 700 includes attaching a base plate to the plurality of sub-displays. Attaching the base plate to the plurality of sub-displays may include attaching the base plate to the plurality of sub-displays via fasteners or an adhesive material. In certain exemplary embodiments, method 700 also includes removing the second vacuum level from the array of vacuum holes to release the sub-displays and removing the sub-displays with the attached base plate from the fixture.

[0054] FIG. 10 is a flow diagram illustrating another example of a method 720 for fabricating a display. At 722, method 720 includes placing a first sub-display on a fixture. In certain exemplary embodiments, the fixture may include glass. The glass may become a part of the assembled display. In other examples, the fixture may include a base plate. The base plate becomes a part of the assembled display. In yet other examples, the fixture comprises a metal frame with standoffs. At 724, method 720 includes laser welding the first sub-display to the fixture. At 726, method 720 includes placing a second sub-display on the fixture.

[0055] At 728, method 720 includes aligning the second sub-display with the first sub-display. Each of the first sub-display and the second sub-display may include an alignment mark. In this case, aligning the second sub-display with the first sub-display includes aligning the alignment mark of the second sub-display with the alignment mark of the first sub-display. At 730, method 720 includes laser welding the second sub-display to the fixture. Each of the first sub-display and the second sub-display may include a backplane and an array

of microLEDs coupled to the backplane. In certain exemplary embodiments, method 720 also includes attaching a base plate to the first sub-display and the second sub-display. In this case, method 720 may also include breaking the laser welds to release the first sub-display and the second sub-display with the attached base plate from the fixture.

[0056] It will be apparent to those skilled in the art that various modifications and variations can be made to embodiments of the present disclosure without departing from the spirit and scope of the disclosure. Thus it is intended that the present disclosure cover such modifications and variations provided they come within the scope of the appended claims and their equivalents.

What is claimed is:

1. A sub-display for a tiled display, the sub-display comprising:
a backplane comprising a first surface, a second surface opposite to the first surface, and an edge surface extending between the first surface and the second surface; and
an array of light sources coupled to the first surface,
wherein the backplane comprises a plurality of alignment marks, each alignment mark configured to emit light when the sub-display is illuminated through the edge surface.
2. The sub-display of claim 1, wherein the backplane comprises glass and each alignment mark of the plurality of alignment marks comprises a defect in glass.
3. The sub-display of claim 1, wherein the backplane comprises four corners and the plurality of alignment marks comprises an alignment mark in each corner.
4. The sub-display of claim 1, wherein each alignment mark of the plurality of alignment marks comprises a cross shape.
5. The sub-display of claim 1, wherein each alignment mark of the plurality of alignment marks is readable by a machine vision system.
6. The sub-display of claim 1, wherein the array of light sources comprises an array of microLEDs.
7. A method for fabricating a display, the method comprising:
placing a plurality of sub-displays on a fixture comprising an array of vacuum holes at a first vacuum level for holding each of the plurality of sub-displays;
aligning the plurality of sub-displays to each other by sliding each sub-display on the fixture;
increasing the vacuum level of the vacuum holes to a second vacuum level such that each of the plurality of sub-displays are immovable; and
attaching a base plate to the plurality of sub-displays.

8. The method of claim 7, further comprising:
 - removing the second vacuum level from the array of vacuum holes to release the sub-displays; and
 - removing the sub-displays with the attached base plate from the fixture.
9. The method of claim 7, wherein spacing between the vacuum holes in the array is set such that each sub-display is held by a plurality of vacuum holes.
10. The method of claim 7, wherein attaching the base plate to the plurality of sub-displays comprises attaching the base plate to the plurality of sub-displays via fasteners or an adhesive material.
11. The method of claim 7, wherein each of the plurality of sub-displays comprises an alignment mark, and
 - aligning the plurality of sub-displays to each other comprises aligning the alignment mark of each of the plurality of sub-displays with the alignment mark of another one of the plurality of sub-displays.
12. The method of claim 7, wherein each sub-display of the plurality of sub-displays comprises a backplane and an array of microLEDs coupled to the backplane.
13. A method for fabricating a display, the method comprising:
 - placing a first sub-display on a fixture;
 - laser welding the first sub-display to the fixture;
 - placing a second sub-display on the fixture;
 - aligning the second sub-display with the first sub-display; and
 - laser welding the second sub-display to the fixture.
14. The method of claim 13, further comprising:
 - attaching a base plate to the first sub-display and the second sub-display.
15. The method of claim 13, wherein the fixture comprises glass.

16. The method of claim 13, wherein the fixture comprises a base plate.
17. The method of claim 13, wherein the fixture comprises a metal frame with standoffs for laser welding to the first sub-display and the second sub-display.
18. The method of claim 13, further comprising:
attaching a base plate to the first sub-display and the second sub-display; and
breaking the laser welds to release the first sub-display and the second sub-display with the attached base plate from the fixture.
19. The method of claim 13, wherein each of the first sub-display and the second sub-display comprises an alignment mark, and
aligning the second sub-display with the first sub-display comprises aligning the alignment mark of the second sub-display with the alignment mark of the first sub-display.
20. The method of claim 13, wherein each of the first sub-display and the second sub-display comprises a backplane and an array of microLEDs coupled to the backplane.

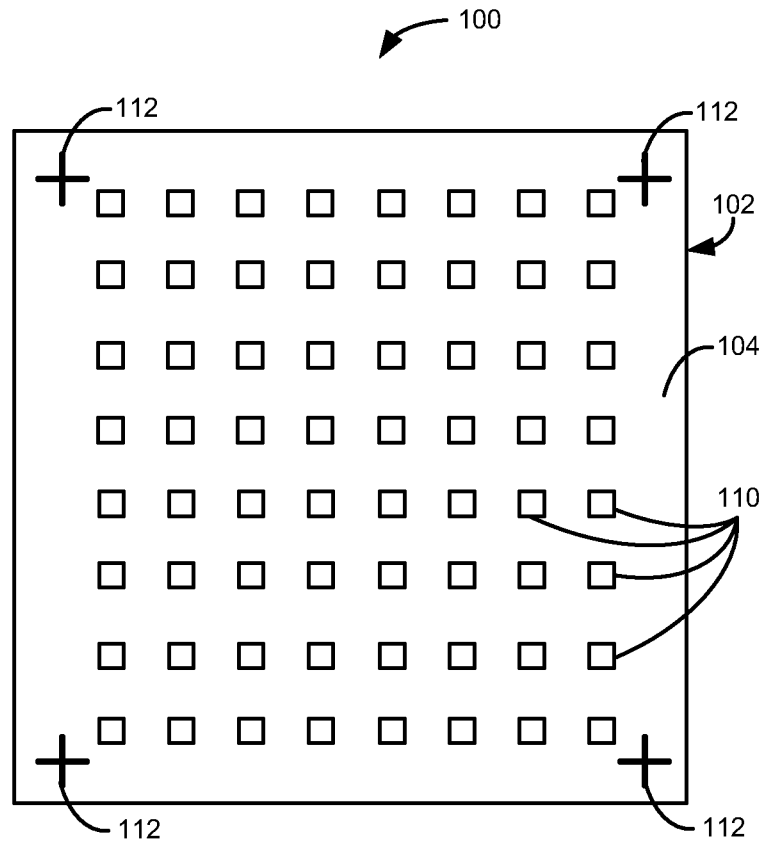


FIG. 1A

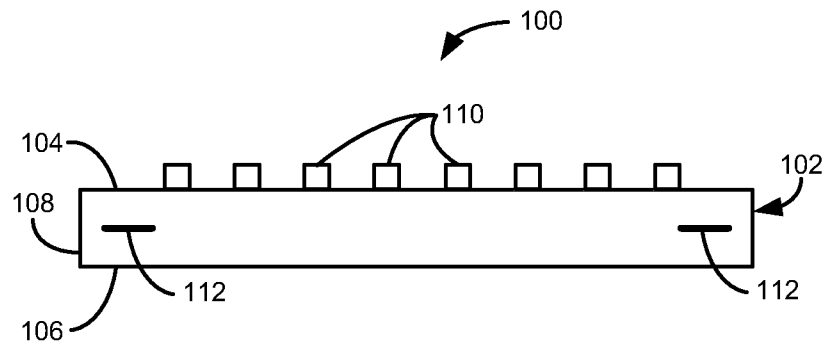


FIG. 1B

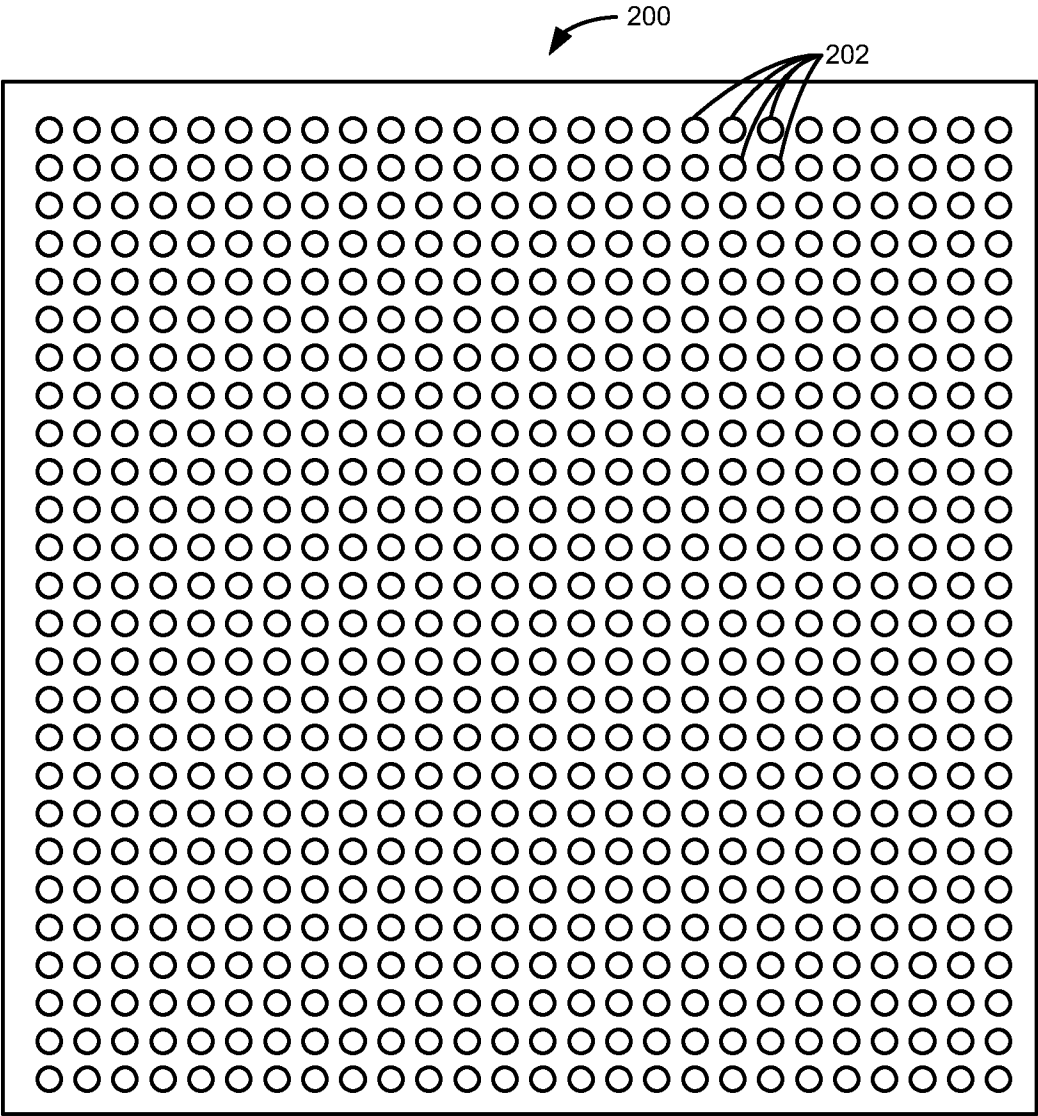


FIG. 2A

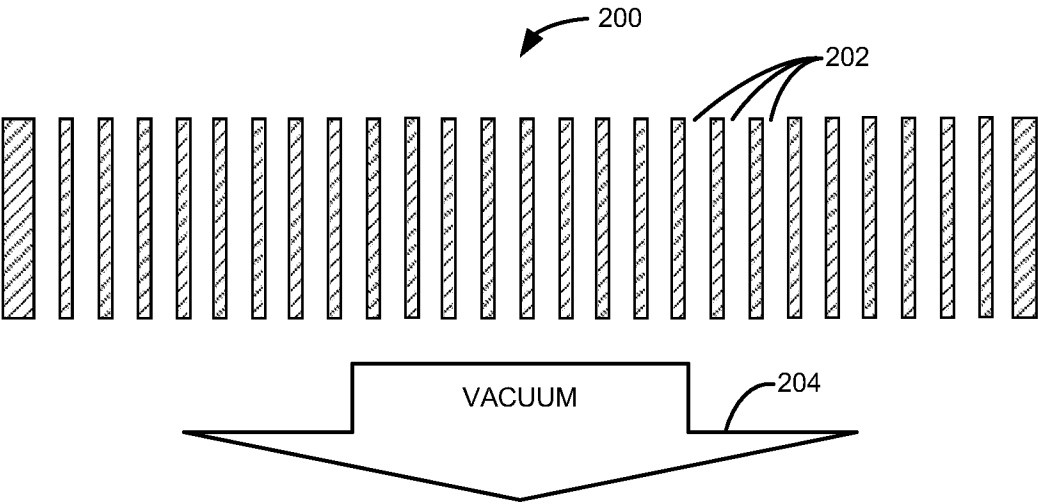


FIG. 2B

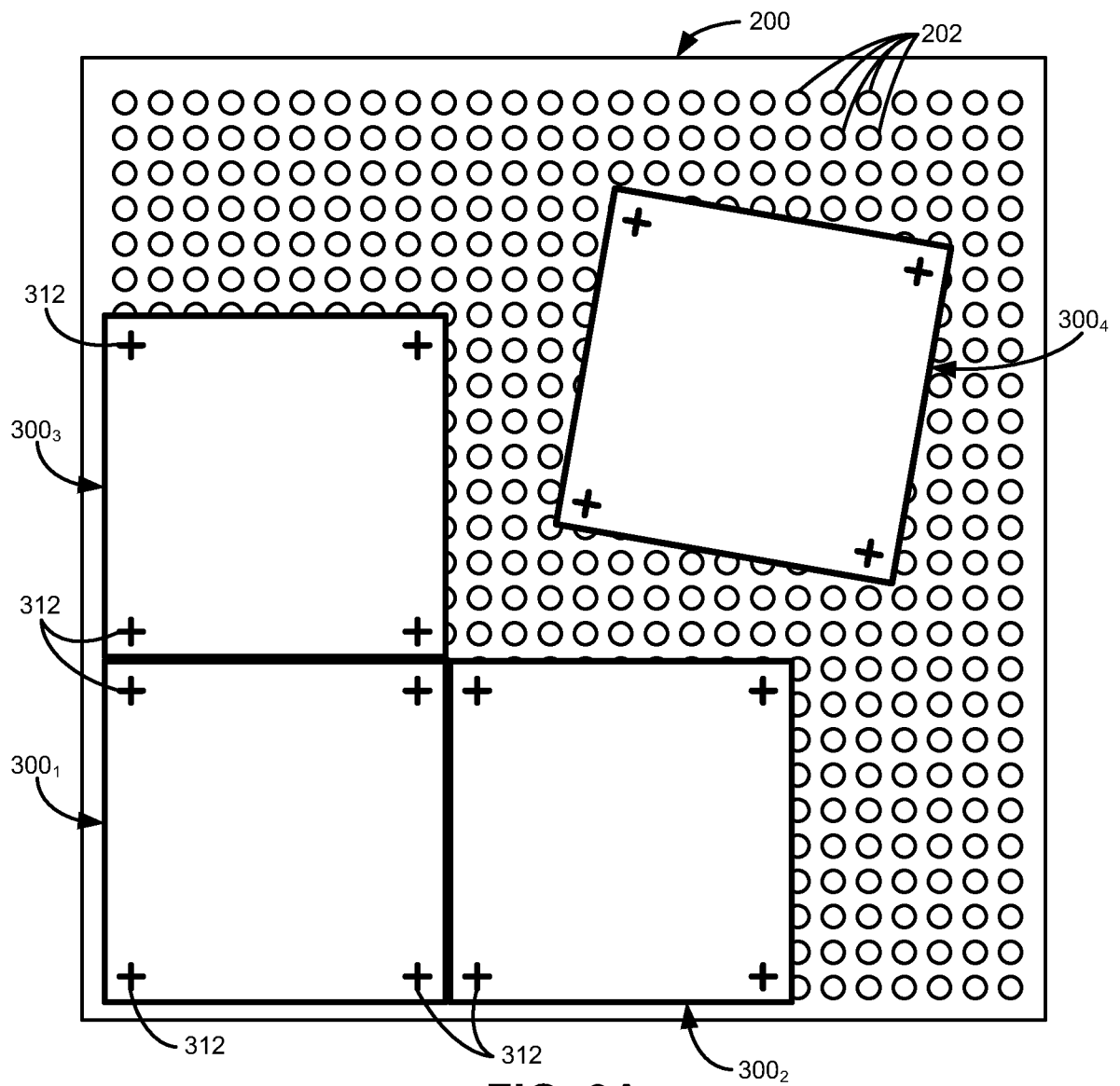


FIG. 3A

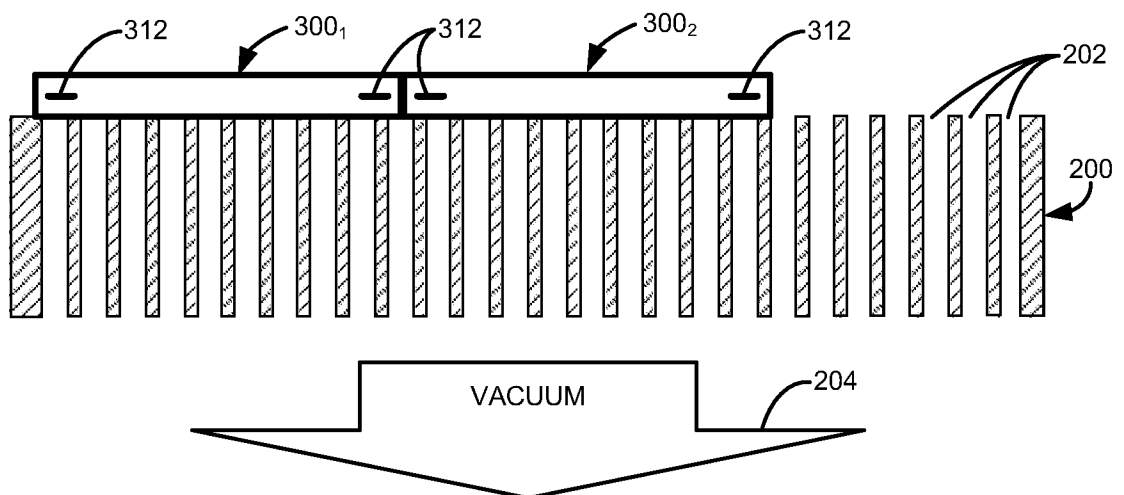


FIG. 3B

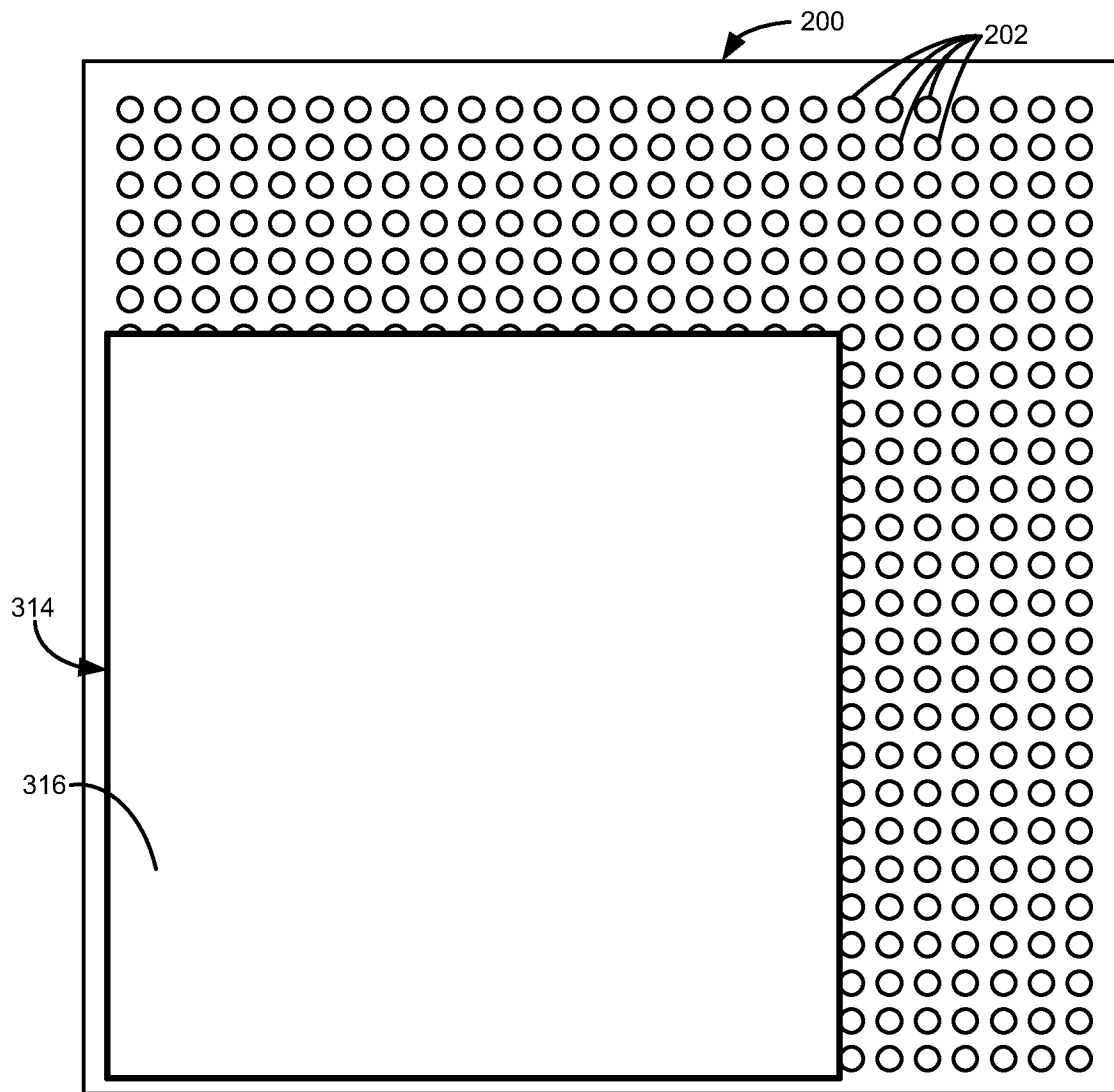


FIG. 4A

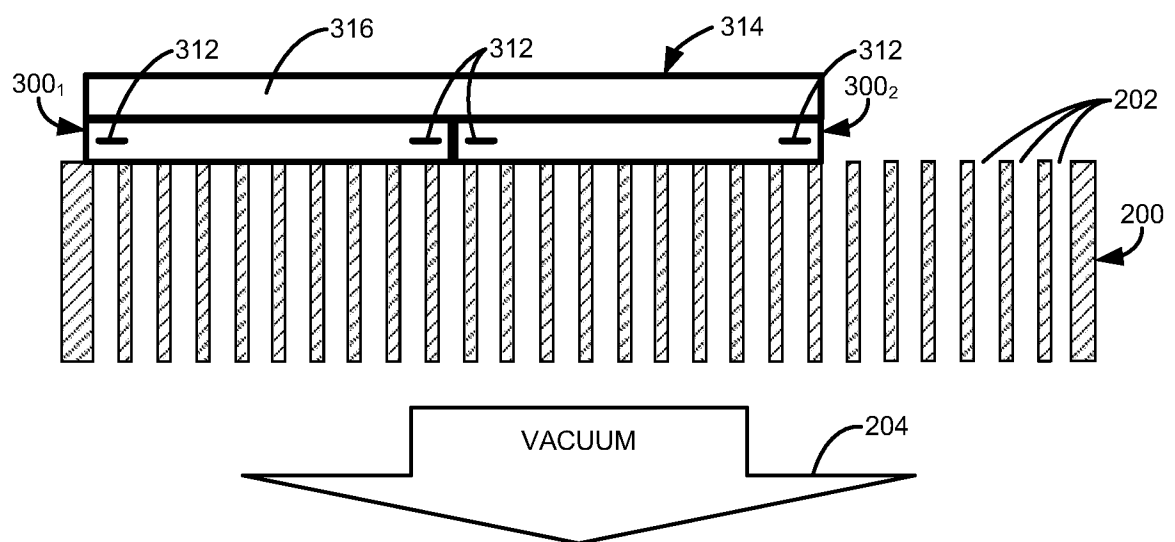


FIG. 4B

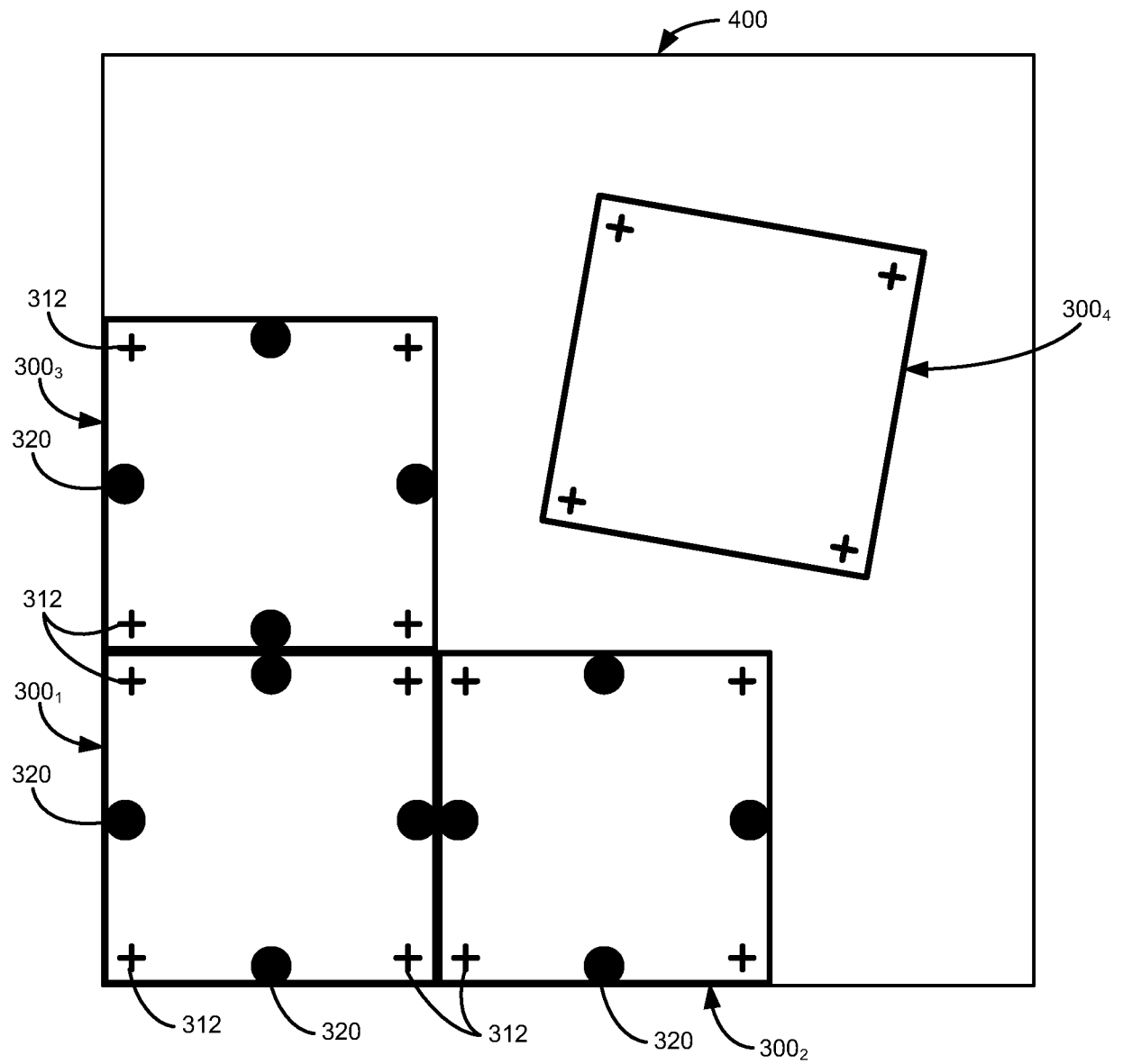


FIG. 5A

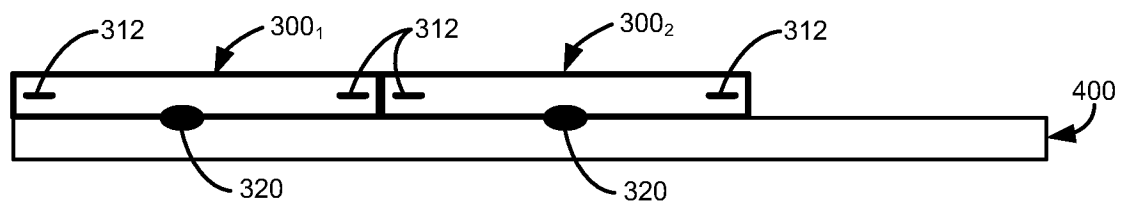


FIG. 5B

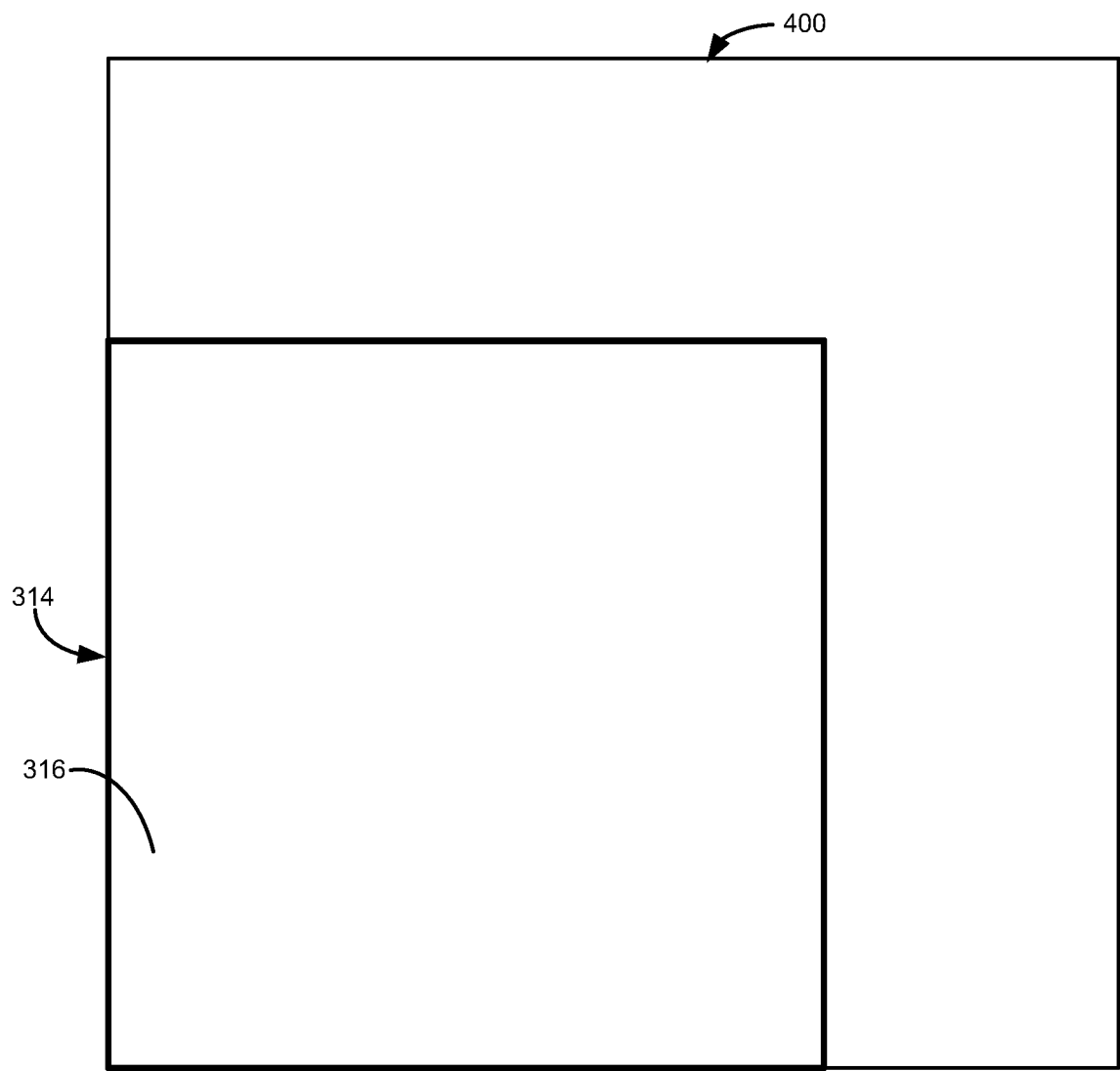


FIG. 6A

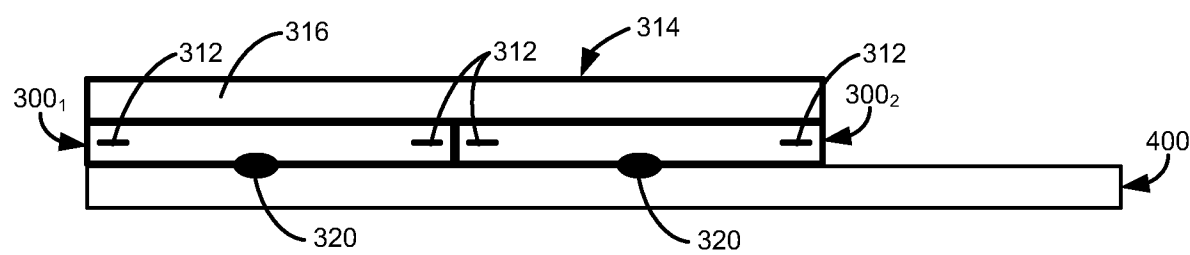


FIG. 6B

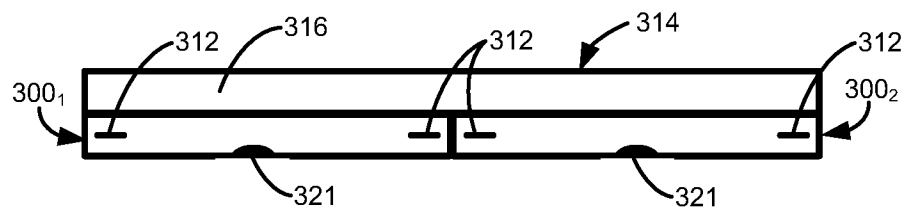


FIG. 6C

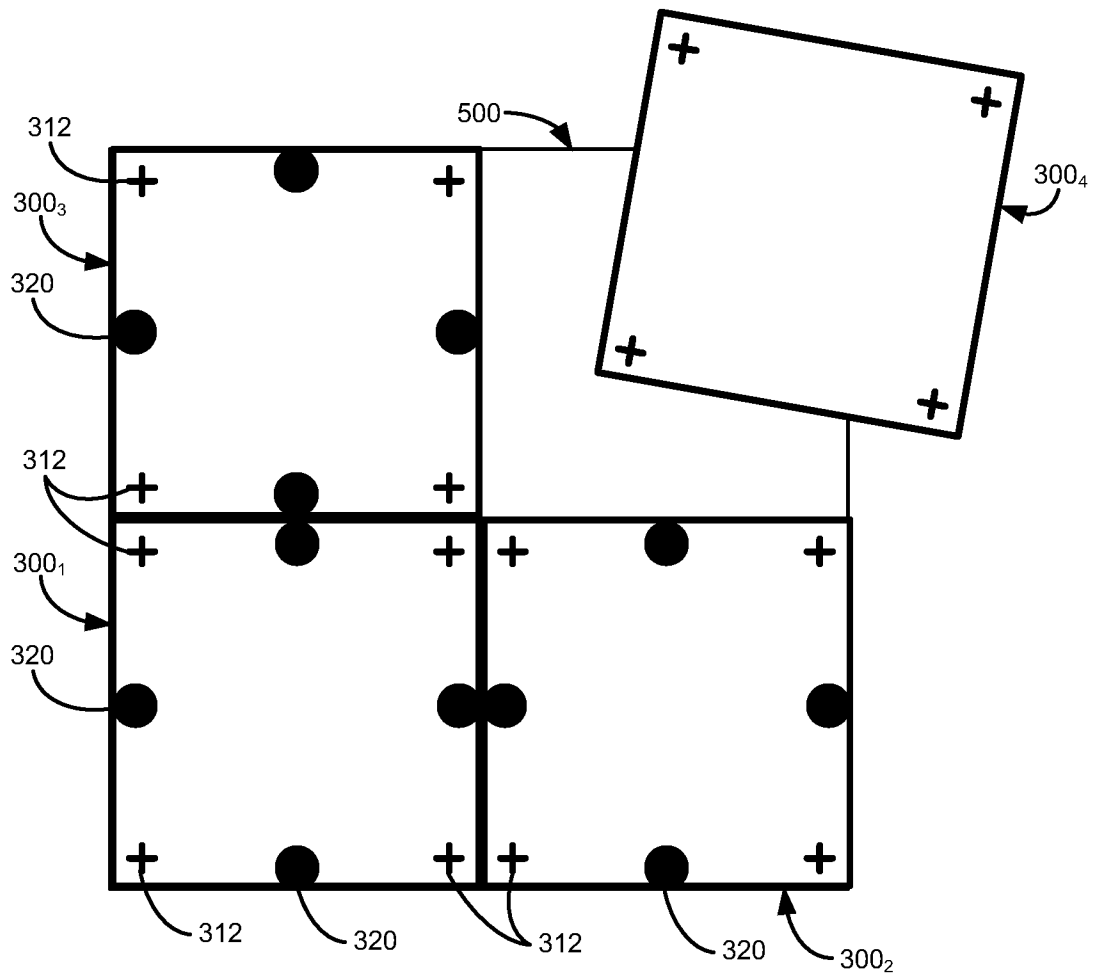


FIG. 7A

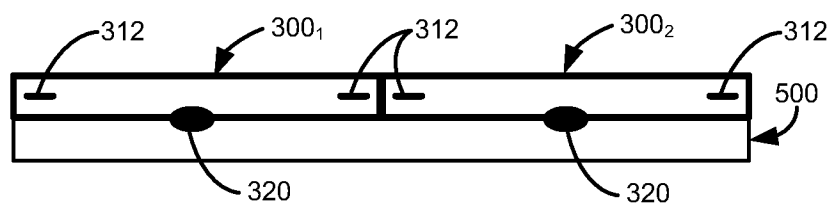


FIG. 7B

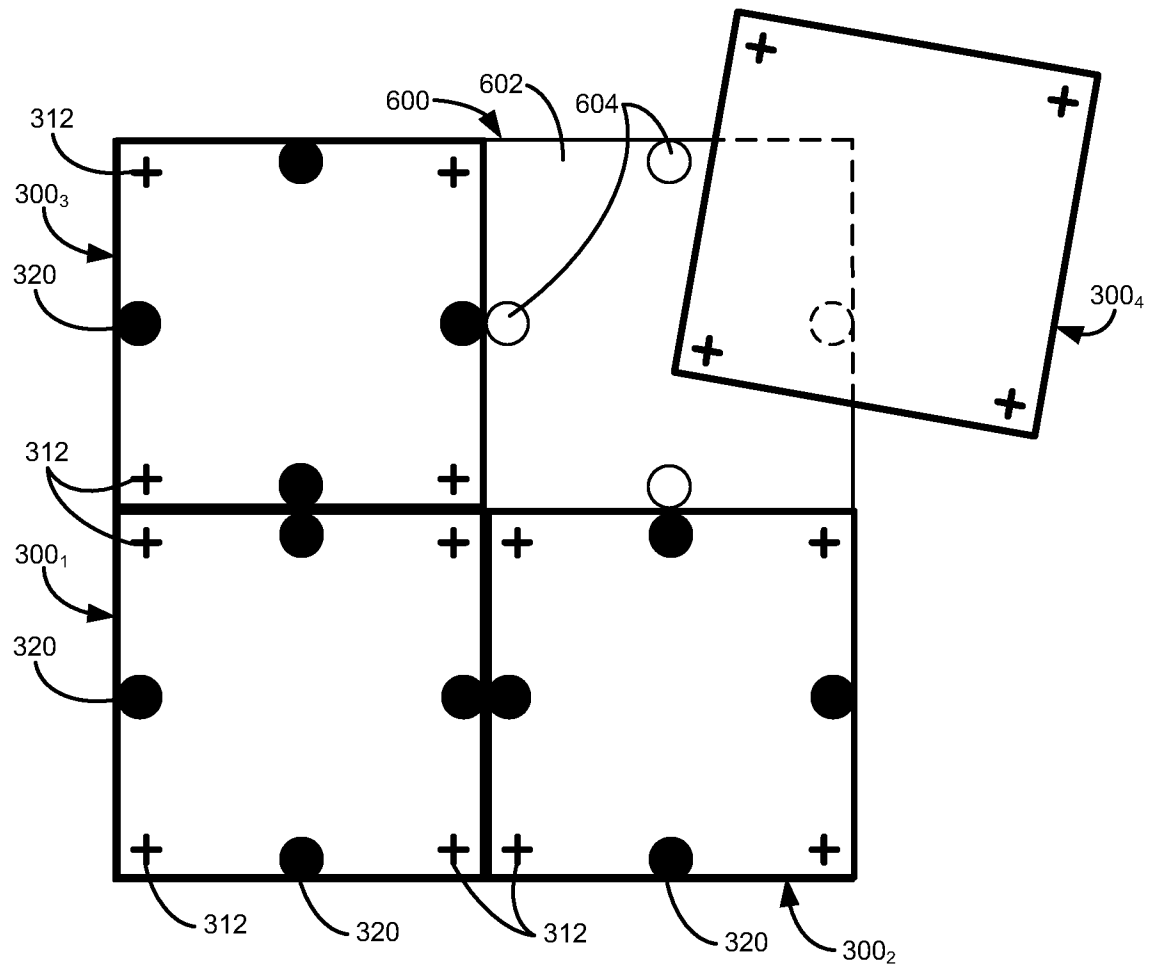


FIG. 8A

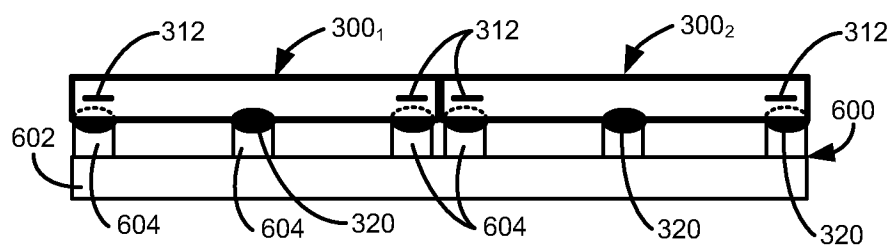
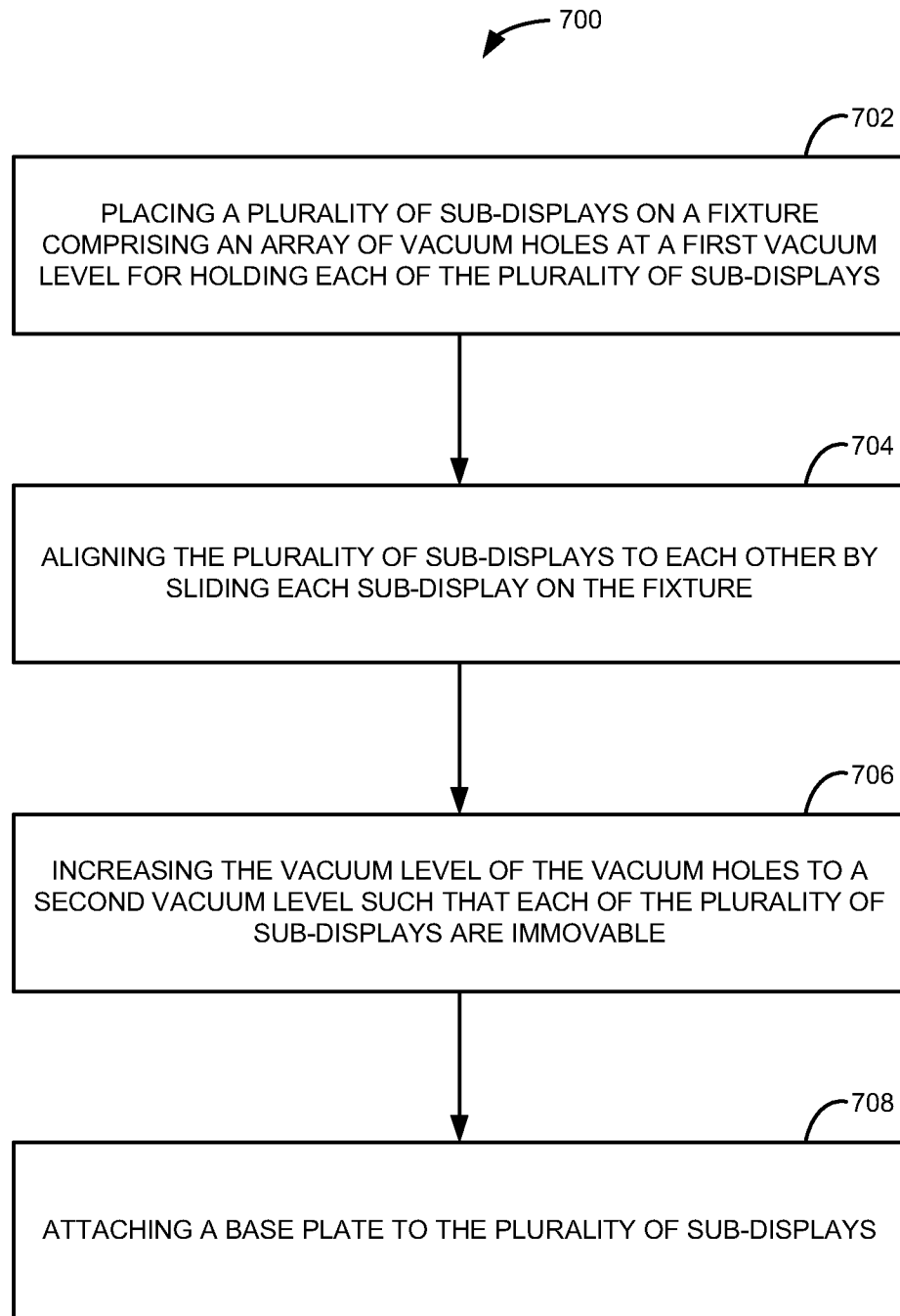
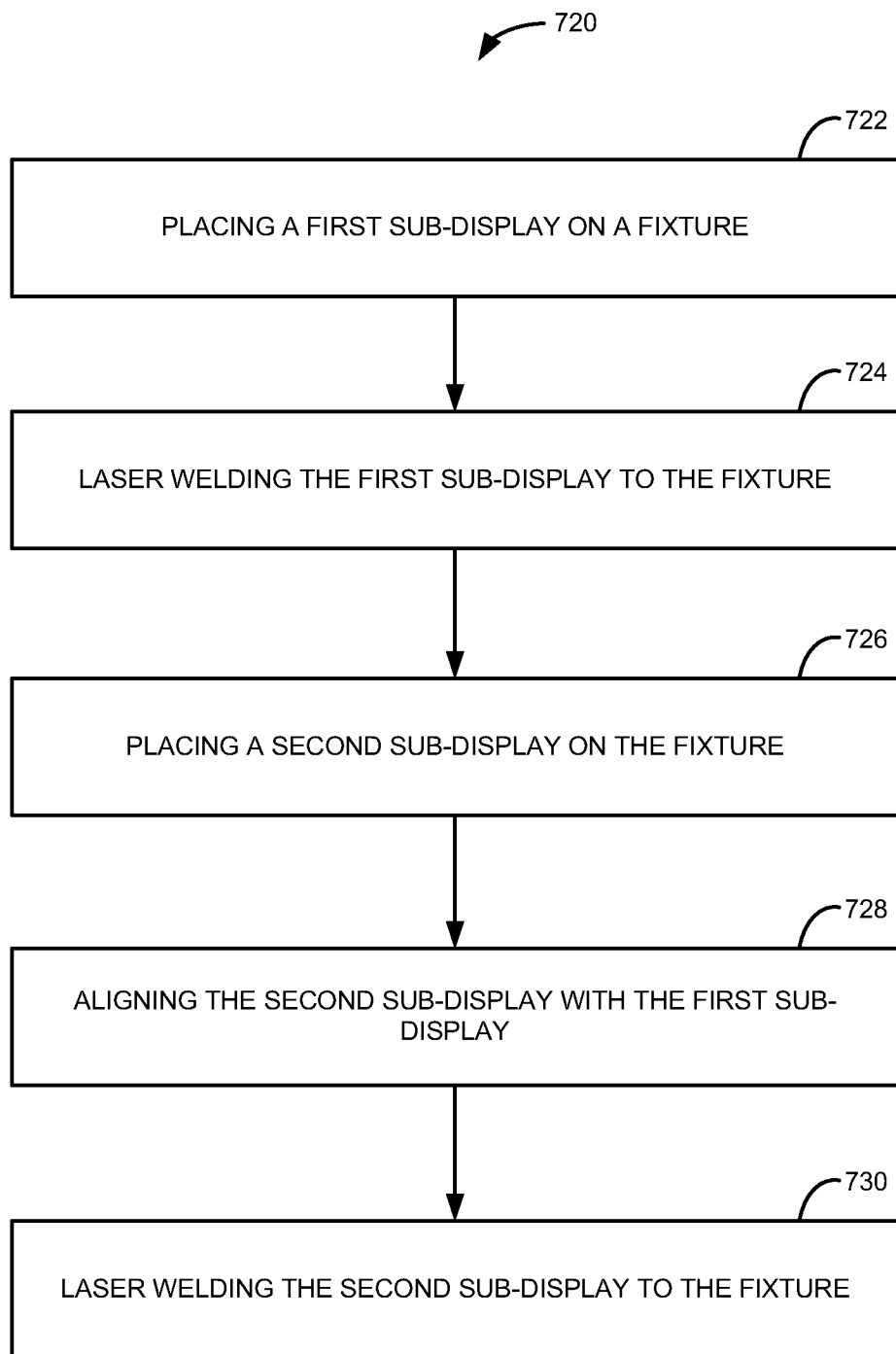


FIG. 8B

**FIG. 9**

**FIG. 10**

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2018/061778**A. CLASSIFICATION OF SUBJECT MATTER****G09F 9/302(2006.01)i, G06F 3/14(2006.01)i, G02F 1/1333(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)

G09F 9/302; B32B 31/00; G01B 11/00; G02F 1/133; G02F 1/1333; G02F 1/1335; G03F 7/20; H01J 9/18; G06F 3/14

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: sub-display, tiled, backplane, surface, edge, array, alignment mark, emit, light, fixture, vacuum, attach, laser welding

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2002-0001051 A1 (J. PETER KRUSIUS et al.) 03 January 2002 See paragraphs [0040]-[0084]; claims 1, 5, 8; and figures 2, 7-8, 11-12.	7-20
Y		1-6
Y	US 8773664 B1 (LEI WANG et al.) 08 July 2014 See column 3, lines 1-2; column 5, lines 59-65; claim 18; and figures 5-6, 9.	1-6
A	US 5711693 A (KEE-SOO NAM et al.) 27 January 1998 See column 3, line 15 - column 6, line 64; and figures 1A-5A.	1-20
A	US 2016-0313588 A1 (GOOGLE INC.) 27 October 2016 See paragraphs [0018]-[0027]; and figures 2-5B.	1-20
A	US 2004-0000368 A1 (MASASHI KASUGA et al.) 01 January 2004 See paragraphs [0078]-[0079], [0125]-[0139]; and figures 4, 22-23.	1-20



Further documents are listed in the continuation of Box C.



See patent family annex.

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"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

08 March 2019 (08.03.2019)

Date of mailing of the international search report

11 March 2019 (11.03.2019)

Name and mailing address of the ISA/KR

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2018/061778

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