



(51) International Patent Classification:

H05K 13/04 (2006.01) *B05C 5/02* (2006.01)
H01L 21/67 (2006.01) *B05C 13/02* (2006.01)
B05C 11/10 (2006.01)

(21) International Application Number:

PCT/US2015/039507

(22) International Filing Date:

8 July 2015 (08.07.2015)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

14/326,722 9 July 2014 (09.07.2014) US

(71) Applicant: **NORDSON CORPORATION** [US/US];
 28601 Clemens Road, Westlake, OH 44145-1119 (US).

(72) Inventors: **GIUSTI, Christopher, L.**; 667 Larkspur Ct.,
 San Marcos, CA 92078 (US). **MAIORCA, Philip, P.**;
 17172 Tam-O-Shanter Drive, Poway, CA 92064 (US).
MEIER, Mark, S.; 1806 Hummock Lane, Encinitas, CA
 92024 (US). **PADGETT, David, N.**; 3041 Glenbrook
 Street, Carlsbad, CA 92010 (US).

(74) Agents: **ABERNATHY, Margaret, A.** et al.; Baker &
 Hostetler LLP, 1050 Connecticut Avenue NW, Suite 1100,
 Washington, DC 20036 (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, 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, KN, KP, KR,
 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))
- before the expiration of the time limit for amending the
 claims and to be republished in the event of receipt of
 amendments (Rule 48.2(h))

(54) Title: DUAL APPLICATOR FLUID DISPENSING METHODS AND SYSTEMS

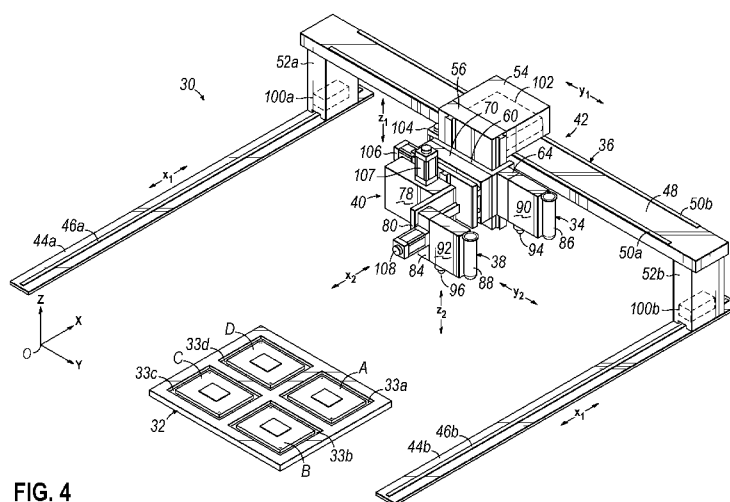


FIG. 4

(57) Abstract: A fluid dispensing system (30) having first and second applicators (34, 38) includes a primary positioner (36) having a first drive (100a, 100b) that moves the first and second applicators (34, 38) simultaneously along a first axis, a second drive (102) that moves the first a second applicators (34, 38) simultaneously along a second axis, and a third drive (104) that moves the first and second applicators (34, 38) simultaneously along a third axis. A secondary positioner (40, 300) is supported by the primary positioner (36) and has a first drive (106, 316) that positions one of the first or second applicators (34, 38) relative to the other along the first axis, a second drive (107, 328) that positions one of the first or second applicators (34, 38) relative to the other along the second axis, and a third drive (108, 344) that positions one of the first or second applicators (34, 38) relative to the other along the third axis. The third drive (108, 344) of the primary positioner (36) moves the secondary positioner (300) along the third axis.

DUAL APPLICATOR FLUID DISPENSING METHODS AND SYSTEMS

Technical Field

[0001] The present invention relates generally to dispensing viscous fluids, and more particularly to dispensing viscous fluids at multiple dispense regions simultaneously with multiple fluid applicators.

Background

[0002] In the manufacture of electronic substrates, such as printed circuit boards ("PCB") for example, it is frequently necessary to apply small, precise amounts of viscous fluids, i.e., those with a viscosity greater than 50 centipoise. Such fluids may include adhesives, solder paste, solder flux, solder mask, underfill material, encapsulants, potting compounds, epoxies, die attach pastes, silicones, RTV, or cyanoacrylates, for example.

[0003] Automated fluid dispensing systems are often used for dispensing patterns of such viscous fluids onto substrates with a high degree of accuracy, repeatability, and efficiency. As used herein, the term "fluid pattern," and variations thereof, refers to one or more lines, arcs, dots, combinations thereof, and/or any other configuration of continuously or intermittently dispensed fluid. Traditional fluid dispensing systems include a fluid applicator, also referred to as a dispenser or valve, mounted to a gantry which is movable for positioning the applicator as desired along three mutually orthogonal axes (X, Y, Z) above one or more substrates positioned generally in the horizontal XY plane. The gantry is generally movable with drive mechanisms controlled by a computer system or other controller. A moving conveyor, generally aligned with the X axis of the dispensing system, may be used to sequentially deliver pluralities of substrates to a location generally beneath a fluid dispensing system. The pluralities of substrates are often organized into and carried by carrier trays, such as a JEDEC[®] tray. The dispensing system may then be operated to dispense a pre-programmed pattern of fluid onto the substrates.

[0004] To dispense a pattern of fluid onto one or more substrates held in a carrier tray, the controller first determines the location and orientation of the substrates in the horizontally-oriented XY plane in which the substrates generally lie. A camera mounted to the gantry scans the substrates and captures visual images of reference fiducials provided on the top surfaces of

each substrate by traveling along a path that moves across the pre-programmed locations of the reference fiducials which are known by the controller. Based on these captured visual images, the controller determines the actual location and orientation of each substrate in the XY plane. A height sensor, also mounted to the gantry, measures the position of each substrate along the vertically-oriented Z axis for determining a proper dispense height at which a dispensing tip of the applicator should be positioned when dispensing onto the substrate. The controller then operates the gantry to move the applicator along the X and Y axes until the applicator is properly positioned in the XY plane over a desired region of a substrate positioned below. The applicator is then lowered along the Z axis until the dispensing tip is at the proper dispensing height, at which point the applicator then dispenses the pre-programmed fluid pattern onto the substrate. Upon completion of dispensing, the applicator is then raised back up along the Z axis and may be repositioned in the XY plane for subsequent dispensing at a new region of the same substrate or of a new substrate.

[0005] For increased manufacturing throughput, fluid dispensing systems have been provided with dual fluid applicators for simultaneously dispensing at first and second dispense regions. As used herein, the term "dispense region" refers to a general region or zone at which a fluid pattern is dispensed. For example, "dispense region" may refer to a substrate generally or it may refer to a particular region of a substrate. Accordingly, the phrase "first and second dispense regions," and variations thereof, may refer to first and second substrates that are physically independent of each other, or alternatively it may refer to first and second distinct regions of a single substrate. For example, a single substrate, such as a panelized substrate, may include a plurality of distinct regions at which fluid is dispensed.

[0006] With traditional fluid dispensing systems, a first applicator is positioned and controlled to dispense at a first dispense region, such as a first substrate, while a second applicator is simultaneously positioned and controlled to dispense at a second dispense region, such as a second substrate. On occasion, the first and second substrates may be rotated in the same way in the XY plane of the dispensing system (i.e., "globally rotated") relative to the X and Y axes. Global rotation of the substrates may occur when the carrier tray in which the substrates are carried is not aligned with the X and Y axes.

Traditional dual dispensing methods have included steps for making an automated, one-time positional adjustment of the second applicator relative to the first applicator along the X and Y axes prior to dispensing to thereby enable simultaneous dispensing of identical fluid patterns onto globally rotated first and second substrates.

[0007] However, traditional dual dispensing methods have not included automatically repositioning the first and second applicators relative to each other along the X or Y axes while actively dispensing. In other words, traditional dual dispensing systems do not perform active, real-time positional adjustments of the first and second applicators relative to each other in the XY plane while dispensing. Consequently, traditional dual dispensing methods have not accomplished accurate simultaneous dispensing of identical fluid patterns at first and second dispense regions, such as first and second substrates, that are rotated relative to each other in the XY plane (i.e., "locally rotated"). For example, a first rectangular substrate may be aligned parallel with the X and Y axes and a second rectangular substrate may be rotated in the XY plane relative to the X and Y axes. Such local rotation may occur when a substrate is sized smaller than the carrier tray pocket in which it sits, thereby forming one or more gaps between the outer perimeter of the substrate and the inner wall of the pocket. The substrate is thus permitted to rotate within the pocket in the XY plane, and relative to any one or more adjacent substrates. Additionally, local rotation may be present among multiple dispense regions of a single substrate, for example a panelized circuit board. Traditional dual dispensing methods are deficient in actively correcting for such local rotation while dispensing.

[0008] Furthermore, traditional dual dispensing methods have not included actively repositioning the first or second applicator relative to each other along the vertical Z axis of the dispensing system while the first and second applicators are dispensing. Accordingly, traditional dual dispensing systems have not accomplished accurate dual dispensing at first and second dispense regions, such as first and second substrates, where the first and second dispense regions are tilted in the XY plane relative to each other, or where one of the dispense regions is uniquely contoured relative to the XY plane, along the Z axis. Thus, dispense regions that are "rotated" relative to each other may lay in a common XY reference plane. In contrast, dispense

regions that are "tilted" and/or "contoured" relative to each other do not lie in a common plane, and the dispense regions are uniquely tilted and/or uniquely contoured relative to the XY reference plane, as described in greater detail below in connection with embodiments of the invention (see *e.g.*, FIG. 13A).

[0009] In illustration of the discussion above, FIG. 1 shows a carrier tray 10 having a plurality of adjacent pockets 12a, 12b, 12c, and 12d for receiving a corresponding plurality of substrates 14a, 14b, 14c, and 14d. As shown, each substrate 14a-14d may include a corresponding component 16a, 16b, 16c, and 16d mounted thereto. Each pocket 12a-12d has a depth in a direction perpendicular to the XY plane, and is sized and shaped to retain the corresponding substrate 14a-14d in a centered position and in proper orientation relative to a global origin O. FIG. 2 shows a carrier tray 20 in which pockets 22a, 22b, 22c, and 22d are sized slightly larger than their corresponding substrates 24a, 24b, 24c, and 24d held therein, such that gaps are created between the outer perimeter of each substrate A-D and the inner walls of its corresponding pocket 22a-22d. Accordingly, each substrate 24a-24d is permitted to shift and thereby become rotated and/or translated in the XY plane relative to its centered orientation (shown in phantom) and relative to each of the other substrates 24a-24d.

[0010] FIG. 3 shows the carrier tray 20 and substrates 24a-24d of FIG. 2, but where substrate 24b is tilted relative to the XY plane. More specifically, FIG. 3A shows an angular offset between a bottom surface 26 of substrate 24b and a base surface 28 of its pocket 22b, thereby forming a wedge-shaped gap 25. Such tilting may be caused by the presence of a foreign material between the bottom surface 26 and the base surface 28. Alternatively, tilting of a substrate may occur if the substrate is malformed, for example through warping. As discussed above, traditional dual dispensing methods have not accomplished automated, real-time adjustment of applicator positioning while dispensing so as to accurately dispense at first and second dispense regions, such as first and second substrates, that are misaligned in the manners shown in FIGS. 2-3A. Accordingly, there is a need for dual dispensing methods and systems that address such deficiencies.

Summary

[0011] An exemplary method is provided for dispensing a first fluid pattern at a first dispense region and a second fluid pattern at a second dispense region. The first and second dispense regions may be first and second independent substrates, as primarily shown and described herein, or they may be separate regions of a common substrate, for example. The first and second dispense regions are positioned relative to a reference plane defined by a first axis and a second axis orthogonal to the first axis. Positions of the first and second dispense regions in the reference plane are determined. Positions of the first dispense region and the second dispense region along a third axis are determined, the third axis being mutually orthogonal with the first and second axes. A first applicator is moved toward the first dispense region with a positioner and the second applicator is moved toward the second dispense region with the positioner. The first fluid pattern is dispensed at the first dispense region with the first applicator and the second fluid pattern is simultaneously dispensed at the second dispense region with the second applicator. The second applicator is moved relative to the first applicator in at least one of a direction parallel to the first axis, a direction parallel to the second axis, or a direction parallel to the third axis while the first applicator dispenses at the first dispense region and the second applicator simultaneously dispenses at the second dispense region.

[0012] Another exemplary method is provided for dispensing a first fluid pattern at a first dispense region and a second fluid pattern at a second dispense region. The first and second dispense regions are positioned relative to a reference plane defined by a first axis and a second axis orthogonal to the first axis. The first dispense region is provided with at least one of a first tilt or a first contour relative to the reference plane and along a third axis mutually orthogonal with the first axis and the second axis. The at least one of the first tilt or the first contour is unique to the first dispense region. The method includes determining a first dispense height path corresponding to the at least one of the first tilt or the first contour of the first dispense region. The first dispense height path is unique to the first dispense region. The method further includes moving the first applicator along the first dispense height path to dispense the first fluid pattern at the first dispense region. Simultaneously, the second applicator is

moved relative to the second dispense region to dispense the second fluid pattern at the second dispense region.

[0013] Another exemplary method is provided for positioning a first applicator for dispensing fluid at a first dispense region and positioning a second applicator for dispensing fluid at a second dispense region. The first dispense region and the second dispense region are positioned relative to a reference plane defined by a first axis and a second axis orthogonal to the first axis. Positions of the first and second dispense regions in the reference plane are determined. Positions of the first dispense region and the second dispense region along a third axis are determined, the third axis being mutually orthogonal with the first and second axes. A primary positioner is controlled to move the first applicator and the second applicator in at least one of a direction parallel to the first axis or a direction parallel to the second axis to position the first applicator relative to the first dispense region. Simultaneously, a secondary positioner coupled to the primary positioner is controlled to move the second applicator relative to the first applicator in at least one of a direction parallel to the first axis or a direction parallel to the second axis to position the second applicator relative to the second dispense region.

[0014] An exemplary dispensing system is provided for dispensing fluid at a first dispense region and a second dispense region. The first and second dispense regions are each positioned relative to a reference plane defined by a first axis and a second axis orthogonal to the first axis. The system includes a first applicator for dispensing fluid at the first dispense region, and a second applicator for dispensing fluid at the second dispense region. A primary positioner is configured to position the first and second applicators for dispensing fluid at the first and second dispense regions. The primary positioner has a first drive that moves the first and second applicators simultaneously in a direction parallel to the first axis, a second drive that moves the first and second applicators simultaneously in a direction parallel to the second axis, and a third drive that moves the first and second applicators simultaneously in a direction parallel to a third axis. The third axis is mutually orthogonal with the first and second axes. A secondary positioner supported by the primary positioner has a first drive that moves one of the first applicator or the second applicator relative to the other of the first applicator or the second applicator in a direction parallel to the first axis, a second drive that moves one

of the first applicator or the second applicator relative to the other of the first applicator or the second applicator in a direction parallel to the second axis, and a third drive that moves one of the first applicator or the second applicator relative to the other of the first applicator or the second applicator in a direction parallel to the third axis. The third drive of the primary positioner moves the secondary positioner in a direction parallel to the third axis. The first drives, the second drives, and the third drives associated with the primary positioner and the secondary positioner are controlled by a system controller.

[0015] An exemplary dispensing system according to another embodiment for dispensing fluid at first and second dispense regions is also provided. The first and second dispense regions are positioned relative to a reference plane defined by a first axis and a second axis orthogonal to the first axis. The dispensing system includes a first applicator for dispensing a first fluid pattern at the first dispense region, and a second applicator for dispensing a second fluid pattern at the second dispense region. The system further includes a first drive that moves the first applicator in a direction parallel to a third axis, the third axis being mutually orthogonal with the first and second axes, and a second drive that moves the second applicator relative to the first applicator in a direction parallel to the third axis. A controller is operatively coupled with the first and second drives, and identifies at least one of a first tilt or a first contour of the first dispense region relative to the reference plane. The controller generates a controller output signal representative of the first tilt or the first contour. In response to the controller output signal, the second drive moves the second applicator relative to the first applicator in a direction parallel to the third axis while the first applicator dispenses the first fluid pattern at the first dispense region and the second applicator simultaneously dispenses the second fluid pattern at the second dispense region.

[0016] Various additional features and advantages of the invention will become more apparent to those of ordinary skill in the art upon review of the following detailed description of the illustrative embodiments taken in conjunction with the accompanying drawings.

Brief Description of the Drawings

[0017] The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate embodiments of the invention

and, together with a general description of the invention given above, and the detailed description of the embodiments given below, serve to explain the principles of the invention.

[0018] FIG. 1 is a top elevational view showing a carrier tray containing a plurality of substrates each aligned in proper, centered orientations.

[0019] FIG. 2 is a top elevational view showing a carrier tray containing a plurality of substrates each rotated or translated from their centered orientations.

[0020] FIG. 3 is a top elevational view similar to FIG. 2, showing a substrate tilted relative to a horizontal XY plane.

[0021] FIG. 3A is a side cross-sectional view taken along line 3A-3A of FIG. 3, showing the substrate tilted relative to the horizontal XY plane.

[0022] FIG. 4 is an isometric schematic view of a dual applicator dispensing system according to an embodiment of the invention.

[0023] FIG. 5 is an isometric schematic view similar to FIG. 3, showing a secondary positioner disassembled from a primary positioner.

[0024] FIG. 6 is a top elevational view of the dispensing system of FIG. 4, further showing a parts carrier tray in which the substrates are each rotated or translated from their centered orientations.

[0025] FIG. 7 is a top elevational view of first and second substrates of FIG. 6, showing positions of first and second applicator dispense tips prior to dispensing first and second fluid patterns.

[0026] FIG. 8 is a top elevational view similar to FIG. 7, showing positions of the applicator dispense tips after dispensing first portions of the fluid patterns.

[0027] FIG. 9 is a top elevational view similar to FIG. 7, showing positions of the applicator dispense tips after dispensing second portions of the fluid patterns.

[0028] FIG. 10 is a top elevational view similar to FIG. 7, showing positions of the applicator dispense tips after dispensing third portions of the fluid patterns.

[0029] FIG. 11 is a top elevational view similar to FIG. 7, showing positions of the applicator dispense tips after dispensing fourth portions of the fluid patterns.

[0030] FIGS. 12A is an isometric view showing a substrate that is tilted relative to an XY plane, and a corresponding dispense height path along which an applicator moves while dispensing onto the tilted substrate.

[0031] FIG. 12B is an isometric view showing a substrate that is contoured relative to the XY plane, and a corresponding dispense height path along which an applicator moves while dispensing onto the contoured substrate.

[0032] Fig. 13A is side elevational view showing first and second dispense regions provided on first and second substrates that are each uniquely tilted and contoured relative to the XY plane, and a unique dispense height path corresponding to each dispense region.

[0033] FIG. 13B is a side elevational view showing first and second dispense regions provided on a single contoured substrate, and a unique dispense height path corresponding to each dispense region.

[0034] FIGS. 14A and 14B present a flow diagram illustrating steps of a method for simultaneously dispensing at first and second dispense regions.

[0035] FIG. 15 is an isometric view of a secondary positioner according to another exemplary embodiment of the invention, showing the secondary positioner disassembled from the primary positioner.

[0036] FIG. 16 is an isometric view of the secondary positioner of FIG. 15, shown partially disassembled.

Detailed Description

[0037] Turning to FIGS. 4 and 5, an exemplary dual applicator fluid dispensing system 30 for dispensing viscous fluids at a plurality of dispense regions, such as independent substrates A, B, C, D held in a carrier tray 32, is shown schematically. While only four substrates A-D are shown herein, arranged in a rectangular configuration in corresponding pockets 33a, 33b, 33c, 33d, the carrier tray 32 may be adapted to carry any desired number of substrates arranged in any desired configuration. Alternatively, the multiple dispense regions may be distinct regions of a single substrate, as discussed above. In this regard, while dispense regions are primarily exemplified herein as multiple independent substrates, it will be appreciated that, alternatively, dispense regions may be part of single common substrate, for example as

shown in FIG. 13B. In one embodiment, the dispense regions may be part of a panelized substrate, such as a panelized circuit board (not shown).

[0038] The carrier tray 32 may be positioned on a conveyor belt (not shown), which may be operated to deliver the carrier tray 32 to a position generally beneath the dispensing system 30 such that the substrates A-D carried therein may be dispensed upon by the dispensing system 30. Alternatively, the carrier tray 32 may be positioned on any other suitable platform, such as a stationary table or pedestal, located generally within an operating perimeter of the dispensing system 30. The dual dispensing system 30 includes a first fluid applicator 34 mounted to a primary positioner 36 and a second fluid applicator 38 mounted to a secondary positioner 40. The secondary positioner 40 is coupled to and movable by the primary positioner 36. The positioners 36, 40 collectively define a gantry 42 for positioning the first applicator 34 for dispensing at a first dispense region and the second applicator 38 for simultaneously dispensing at a second dispense region, as described in greater detail below.

[0039] The dual dispensing system 30 defines a global origin O and three mutually orthogonal global axes X, Y, and Z. The primary positioner 36 is movable in directions parallel to the global X, Y, and Z axes, denoted generally by x_1 , y_1 , and z_1 , respectively, and corresponding directional arrows. Similarly, the secondary positioner 40 is also movable in directions parallel to the global X, Y, and Z axes, denoted generally by x_2 , y_2 , and z_2 , respectively, and corresponding directional arrows.

[0040] The primary positioner 36 includes a pair of opposed x_1 supports 44a and 44b aligned parallel with the X axis and shown generally as longitudinal beams. The x_1 supports 44a, 44b are each provided with an x_1 bearing, shown as linear bearing guides 46a and 46b, for enabling x_1 linear movement of the applicators 34, 38 parallel to the X axis. The primary positioner 36 further includes a transversely oriented y_1 support 48 aligned parallel with the Y axis and shown generally as a lateral beam. The y_1 support 48 is provided with a pair of y_1 bearings, shown as linear bearing guides 50a and 50b, for enabling y_1 linear movement of the applicators 34, 38 parallel to the Y axis. The y_1 support 48 is movably coupled to the x_1 supports 44a, 44b through a pair of opposed legs 52a and 52b, which engage and are slidable along the x_1 bearing guides 46a, 46b, respectively, for x_1 movement. The

primary positioner 36 further includes a y_1 carriage 54 having a lower XY surface that engages and is slidable along the y_1 bearing guides 50a, 50b for y_1 movement. The y_1 carriage 54 has a YZ surface (i.e., a surface lying in the YZ plane) to which is attached a vertically oriented z_1 support 56, aligned parallel with the Z axis and shown generally in the form of a plate. The z_1 support 56 includes a pair of vertically oriented z_1 bearings, shown as linear bearing guides 58a and 58b, for enabling z_1 linear movement of the applicators 34, 38 in a direction parallel to the Z axis. As shown, the z_1 bearing guides 58a, 58b may be provided on adjacent XZ and YZ surfaces, respectively, of the z_1 support 56. A z_1 carriage 60, shown in the form of an L-shaped bracket, has a first leg 62a and a second leg 62b that engage and are slidable along the z_1 bearing guides 58a, 58b, respectively, for z_1 movement. A first applicator mounting mechanism 64 may be coupled to the second leg 62b and may be configured to releasably support the first applicator 34, as described in greater detail below.

[0041] The secondary positioner 40 is coupled to the primary positioner 36 and enables x_2 , y_2 , and z_2 movements of the second applicator 38 relative to the primary positioner 36 and the first applicator 34 mounted thereon. The secondary positioner 40 includes a y_2 support 70 which may act as a base plate and may be rigidly coupled at a YZ surface to the first leg 62a of the z_1 carriage 60 of the primary positioner 36. The y_2 support 70 may include a pair of y_2 bearings, shown as linear bearing guides 72a and 72b, which may be positioned adjacent to each other on an opposed YZ surface of the y_2 support 70. The y_2 bearing guides 72a, 72b are aligned parallel with the Y axis to enable y_2 movement of the second applicator 38 relative to the primary positioner 36. The secondary positioner 40 further includes a z_2 support 74, shown generally as a plate. A YZ surface of the z_2 support 74 may engage and be slidable along the y_2 bearing guides 72a, 72b for y_2 movement. An opposed YZ surface of the z_2 support 74 may include a pair of z_2 bearings, shown as linear bearing guides 76a and 76b, which are aligned parallel with the Z axis to enable z_2 movement of the second applicator 38 relative to the primary positioner 36.

[0042] A z_2 carriage 78, shown generally in the form of a plate, may include a YZ surface that engages and is slidable along the z_2 bearing guides 76a, 76b for z_2 movement. An x_2 support 80 may be rigidly coupled to an XZ surface of the z_2 carriage 78, in a perpendicular orientation. Alternatively, the x_2

support 80 and the z_2 carriage 78 may be formed integrally. The x_2 support 80 may include an x_2 bearing, shown as a linear bearing guide 82, that is aligned parallel with the X axis to enable x_2 movement of the second applicator 38 relative to the primary positioner 36. A second applicator mounting mechanism 84 may engage and be slidable along the x_2 bearing guide 82 for x_2 movement, and may be configured to releasably support the second applicator 38, as described in greater detail below.

[0043] The first and second applicator mounting mechanisms 64, 84 may be configured to receive and releasably engage the first and second applicators 34, 38, respectively. For example, the applicator mounting mechanisms 64, 84 may each include a quick-disconnect feature (not shown) that enables proper alignment with the corresponding applicator 34, 38 through one or more projections and mating recesses. U.S. Patent No. 6,214,117 and EP Patent No. 1 165 250 B1, the disclosures of which are hereby incorporated by reference herein, show prior art examples of quick disconnect mechanisms for mounting applicators to mechanisms for moving the applicators.

[0044] The first and second applicators 34, 38 may be of any preferred type suitable for a user's intended application, such as an air-operated needle valve or jet of the types made available by Nordson ASYMTEK® of Carlsbad, California, for example. As shown best in FIGS. 4 and 5, each applicator 34, 38 may be in the form of a pneumatically operated jetting valve such as a DispenseJet® DJ-9000 valve available from Nordson ASYMTEK®. As shown, each applicator 34, 38 may include a corresponding fluid reservoir 86, 88 for storing viscous fluid, an actuator 90, 92, for jetting, or dispensing, viscous fluid from a dispensing tip 94, 96 for application to a substrate A-D positioned beneath the dispensing tip 94, 96. An example of a suitable dispenser is shown in U.S. Patent No. 8,578,729, the disclosure of which is hereby incorporated by reference herein. As discussed above, the viscous fluid may be any solder paste, underfill material, adhesive, or encapsulant, for example.

[0045] Movement of the primary and secondary positioners 36, 40 may be preferably accomplished through a series of controllable, powered drive mechanisms. More specifically, each direction of movement x_1 , y_1 , z_1 , x_2 , y_2 , and z_2 may be powered by at least one corresponding powered drive mechanism. As shown, a pair of x_1 drive mechanisms 100a and 100b may operate in parallel to power x_1 movement along the x_1 bearing guides 46a, 46b,

respectively, and may be provided internally within or adjacent to the legs 52a, 52b, respectively. Alternatively, x_1 movement may be powered by a single drive mechanism (not shown). A y_1 drive mechanism 102 may power y_1 movement along the y_1 bearing guides 50a, 50b and may be provided internally within or adjacent to the y_1 carriage 54, as shown. A z_1 drive mechanism 104 may power z_1 movement along the z_1 bearing guides 58a, 58b and may be provided adjacent to an external XZ surface of the z_1 support 56, as shown. A y_2 drive mechanism 106 may power y_2 movement along the y_2 bearing guides 72a, 72b and may be provided adjacent to an external XZ surface of the y_2 support 70, as shown. A z_2 drive mechanism 107 may power z_2 movement along the z_2 bearing guides 76a, 76b and may be provided adjacent to an external upper XY surface of the z_2 carriage 78, as shown. An x_2 drive mechanism 108 may power x_2 movement along the x_2 bearing guide 82 and may be provided adjacent to an external YZ surface of the second applicator mounting mechanism 84, as shown.

[0046] In one embodiment, the drive mechanisms 100a, 100b, 102, 104, 106, 107, 108 may include stepper motors. Alternatively, the drive mechanisms 100a, 100b, 102, 104, 106, 107, 108 may include any other suitable electric, pneumatic, or hydraulic drive adapted to movement with a high degree of accuracy, repeatability, and stability. Additionally, the drive mechanisms 100a, 100b, 102, 104, 106, 107, 108 may include any additional mechanical drive elements suitable for moving the positioners 36, 40. For example, in one embodiment (not shown) the drive mechanisms 100a, 100b, 102, 104, 106, 107, 108 may include stepper motors each having an output shaft connected with a flexible drive coupling to a lead screw. The lead screw may rotate with the motor and engages a threaded or toothed element mounted on a corresponding support to actuate movement along a corresponding linear bearing guide. The drive mechanisms 100a, 100b, 102, 104, 106, 107, 108 may be mounted at any suitable locations within the dispensing system 30 different from those shown and described herein.

[0047] As presented above, the secondary positioner 40 is coupled to the primary positioner 36 and thus the x_1 , y_1 , and z_1 movements of the primary positioner 36 are transferrable to the secondary positioner 40 and the second applicator 38 mounted thereon. The secondary positioner 40 enables additional movements x_2 , y_2 , and z_2 relative to the primary positioner 36, which

movements may be relatively fine in comparison to the corresponding x_1 , y_1 , and z_1 movements performed by the primary positioner 36. Accordingly, in one embodiment, the secondary positioner 40 is movable with ranges of motion that are less than corresponding ranges of motion of the primary positioner 36. More specifically, the primary positioner may have a range of motion in each of the directions parallel to the X axis, the Y axis, and the Z axis (i.e., x_1 , y_1 , and z_1 movements). Similarly, the secondary positioner 40 may have a range of motion in each of the directions parallel to the X axis, the Y axis, and the Z axis (i.e., x_2 , y_2 , and z_2 movements). The ranges of motion of the secondary positioner 40 may be smaller than the corresponding ranges of motion of the primary positioner 36. In this manner, the primary positioner 36 may perform a primary movement to move the first applicator 34 and the second applicator 38, the primary movement defined by any one or combination of x_1 , y_1 , and z_1 movements and having a magnitude. Simultaneously, the secondary positioner 40 may perform a secondary movement relative to the primary positioner 36 to move the second applicator 38 relative to the first applicator 34, the secondary movement defined by any one or combination of x_2 , y_2 , and z_2 movements and having a magnitude that is less than the magnitude of the primary movement.

[0048] Accordingly, the first applicator 34 may be positioned with the primary positioner 36, and the second applicator 38 may be jointly positioned by the primary positioner 36 and the secondary positioner 40. More specifically, the first applicator 34 and the second applicator 38 are both positionable with x_1 , y_1 , and z_1 movements. The second applicator 38 is additionally positionable with x_2 , y_2 , and z_2 movements made relative to the primary positioner 36. Thus, the structural configuration of the dispensing system 30 enables the second applicator 38 to be moved relative to the first applicator 34 in directions parallel to the X, Y, and Z axes. Thereby, the first and second applicators 34, 38 may simultaneously dispense first and second fluid patterns onto first and second substrates, respectively, where the fluid patterns are substantially identical in size and shape and where the substrates are misaligned relative to each other. As described above, the fluid patterns may include one or more lines, arcs, dots, combinations thereof, and/or any other configuration of continuously or intermittently dispensed fluid.

[0049] The primary positioner 36 and the secondary positioner 40 are independently controllable with at least one controller (not shown), such as a

computer. Preferably, the controller is configured to instruct the x_1 , y_1 , and z_1 movements of the primary positioner 36, and to simultaneously instruct the x_2 , y_2 , and z_2 movements of the secondary positioner 40 by controlling the drive mechanisms 100a, 100b, 102, 104, 106, 107, 108. In this manner, the primary positioner 36 is controllable such that the first applicator 34 may be properly positioned relative to and dispense at a first dispense region, such as substrate A. Simultaneously, the secondary positioner 40 is independently controllable such that the second applicator 38 may be properly positioned relative to and dispense at a second dispense region, such as substrate B. As discussed in greater detail below, the positioners 36, 40 are controllable to account for misalignment between a first dispense region and a second dispense region, such as substrates A and B, for example.

[0050] Having just described a dispensing system that is novel in structure, methods of simultaneously dispensing at first and second dispense regions will now be described. The methods are described herein with reference to substrates A, B, C, D shown in FIGS. 6-11. As discussed above, persons skilled in the art will appreciate that the dispensing methods described herein may be adapted for simultaneously dispensing at any two dispense regions of a plurality of dispense regions with the dispensing system 30. For example, first and second dispense regions may be part of a single substrate, such as a panelized substrate.

[0051] The dispensing system 30 may first identify the location and orientation of each substrate A, B, C, D in the XY plane relative to a global origin O, based on the positions of at least two reference fiducials 110a, 110b provided on each substrate A-D. For example, with reference to substrate A, the two fiducials 110a, 110b may be provided at opposing corners of an upper XY surface of the substrate A. While shown herein as an "x" enclosed by a circle, the fiducials 110a, 110b may be any identifiable mark such as a letter, number, dot, or pattern, for example. In this manner, the dispensing system 30 may determine whether each substrate is rotated and/or translated in the XY plane relative to a corresponding reference position defined with respect to origin O.

[0052] The dual dispensing system 30 includes a camera 112 for identifying the reference fiducials 110a, 110b. The camera 112 may be mounted to the gantry 42 at any suitable location, such as a portion of the

secondary positioner 40, as shown in FIG. 6. For fiducial identification, the gantry 42 may be controlled to move the camera 112 along a pre-programmed path based on expected locations of the fiducials 110a, 110b in the XY plane. In one mode, the gantry 42 may be controlled to sequentially pause at the expected location of each fiducial 110a, 110b so that the camera 112 may capture a visual image of a fiducial 110a, 110b during each pause. In another mode, the gantry 42 may be controlled to continuously move and the camera 112 may capture visual images of the fiducials 110a, 110b during movement. Based on the images of the fiducials 110a, 110b captured by the camera 112, the controller may then determine the actual position of each substrate A, B, C, D in the XY plane.

[0053] The dual dispensing system 30 further includes a height sensor 114 for performing height sensing operations, which may include measuring the position of each substrate A-D along the Z axis, relative to the XY plane. The height sensor 114 may be a non-contact laser sensor, or alternatively may be a contact mechanical sensor. In operation, the gantry 42 may be controlled to move the height sensor 114 along a pre-programmed path for measuring the position each substrate A-D along the Z axis. These measurements, referred to herein as Z height measurements, enable the controller to determine for each substrate A-D a proper height along the Z axis, referred to as a dispense height, to which the dispensing tip 94, 96 of the first or second applicator 34, 38 should be lowered for dispensing fluid onto the substrate A-D. In this manner, the system 30 may ensure a proper dispense gap between the dispensing tips 94, 96 and the corresponding substrates A-D while dispensing.

[0054] As shown in FIG. 6, the substrates A-D may lie generally parallel to the XY plane, and thus a single height measurement for each substrate A-D may be sufficient. Alternatively, one or more of the substrates A-D may be tilted relative to the XY plane (see, e.g., FIGS. 3A, 12A) such that the surface to be dispensed upon is positioned at various points along the Z axis. In such case, the height sensor 114 may be operated to measure multiple heights of the tilted substrate and thereby map the tilt along the Z axis. Similarly, multiple Z height measurements may be collected for a substrate having a surface, onto which fluid is to be dispensed, that is contoured relative to the XY plane and along the Z axis (referred to herein as a "contoured substrate," and similar variations thereof), as shown in FIGS. 12B-13B, for example. The height sensor 114 may

then generate a sensor output signal that is representative of the tilt and/or contour of the substrate and that is based on the multiple height measurements collected, which signal is then communicated to the controller. The camera 112 and height sensor 114 may be integrated into a single system operable by the controller for collecting fiducial information and height measurements for each of the substrates A-D to be dispensed upon.

[0055] Alternatively, Z height measurement information corresponding to the substrates to be dispensed upon may be read into the controller from an electronic data file that is accessed by the controller and which may be made available by the user. In such case, the height sensor 114 may be used to detect the XY plane relative to which the substrates are positioned, thereby providing the controller with a reference plane to which the Z height data provided to the controller may be applied.

[0056] In response to the sensor output signal, or to electronic data read from an external electronic data file, the controller identifies the tilt and/or contour of the substrates to be dispensed upon, and then generates one or more controller output signals for dictating z_1 and/or z_2 movements that the primary positioner 36 and/or the secondary positioner 40 must actively perform during dispensing in order to accommodate the tilted orientation of the substrate and/or its contoured surface. Such controller output signals are representative of the tilt and/or contour of the substrates.

[0057] Based on the information provided to the controller during the fiducial locating and height sensing operations described above, the primary and secondary positioners 36, 40 may be operated to simultaneously position the first applicator 34 relative to a first substrate and the second applicator 38 relative to a second substrate. The first applicator 34 may then dispense a first fluid pattern onto the first substrate while the second applicator 38 simultaneously dispenses a second, identical fluid pattern onto the second substrate. The positioners 36, 40 are automatically movable while dispensing to actively correct for any positional misalignment of one of the substrates relative to the other. These positioning and dispensing steps may be performed with respect to any two of the substrates A-D, for example, which are each rotated and/or translated along the X and Y axes relative to each of the other substrates A-D, as shown in FIGS. 6-11.

[0058] FIGS. 7-11 show a series of steps in which the first applicator 34 is positioned relative to substrate A and dispenses a fluid pattern 116 thereon. Simultaneously, the second applicator 38 is positioned relative to substrate B and dispenses a substantially identical fluid pattern 118 thereon. Substrates A and B are shown each misaligned from their respective centered positions within their respective pockets 33a, 33b (see, e.g., FIG. 2). The geometric centers of the pockets 33a, 33b in the XY plane are represented by crosshairs. As shown, substrate A is rotated from its centered position relative to the X and Y axes, while substrate B is translated from its centered position along the X and Y axes. Accordingly, substrates A and B are rotated and translated relative to each other with respect to the X and Y axes. As described below, the second applicator 38 is movable in the XY plane relative to the first applicator 34 while dispensing to thereby actively and automatically correct for misalignments of the substrates A, B in the XY plane.

[0059] As shown, the first and second applicator dispensing tips 94, 96 are each represented in FIGS. 7-11 by a pair of concentric phantom circles. The shapes of the fluid patterns 116, 118 to be dispensed are represented by directional arrows forming generally rectangular outlines about the perimeters of components 120a, 120b provided on the substrates A, B. Accordingly, FIGS. 7-11 simulate dispensing of an adhesive underfill material which is dispensed along the edge of a component, such as a flip chip having a grid of solder balls on its underside which are positioned on corresponding matching contact pads on the substrate, with the underfill material flowing under the chip and around the solder balls to secure the flip chip to the substrate. Persons of ordinary skill in the art will appreciate that the positioners 36, 40 and the applicators 34, 38 mounted thereon may be controlled to dispense fluid patterns of any other desired shape and at any other desired region of one or more substrates or other similar workpieces. For example, as discussed above, the fluid patterns may include one or more lines, arcs, dots, combinations thereof, and/or any other configuration of continuously or intermittently dispensed fluid.

[0060] Referring to FIG. 7, the controller may command the primary positioner 36 to execute x_1 and y_1 movements to thereby position the first applicator dispensing tip 94 to overlie a first dispense site 122 on substrate A. Simultaneously, the controller may command the secondary positioner 40 to execute x_2 and y_2 movements relative to the primary positioner 36 to thereby

position the second applicator dispensing tip 96 over a corresponding first dispense site 124 on substrate B. The controller may then command the primary positioner 36 to execute downward z_1 movement to thereby advance the first and second dispensing tips 94, 96 simultaneously toward their proper dispense heights, as determined during the height sensing operation described above. If the controller determines, through the height sensing operation, that substrates A and B are each positioned at the same location along the Z axis, the first and second dispensing tips 94, 96 may be positioned at the same dispense height through z_1 movement of the primary positioner 36. If the controller determines, through the height sensing operation, that substrates A and B are positioned at different locations along the Z axis, the controller may additionally command the secondary positioner 40 to execute z_2 movement relative to and simultaneously with the z_1 movement of the primary positioner 36. Thereby, the first and second dispensing tips 94, 96 may be simultaneously positioned at their proper, respective dispensing heights. The dispensing system 30 may now dispense onto substrates A and B.

[0061] As shown in FIG. 8, the first applicator 34 and its dispensing tip 94 may be moved by the primary positioner 36 to dispense a first leg 116a of fluid pattern 116. Simultaneously, the second applicator 38 and its dispensing tip 96 may be moved by the secondary positioner 40 relative to the primary positioner 36 and the first applicator 34 to dispense a first leg 118a of fluid pattern 118. More specifically, the controller may command the primary positioner 36 to execute x_1 and y_1 movements, and further command the secondary positioner 40 to simultaneously execute corrective x_2 and y_2 movements relative to the primary positioner 36. The controller may issue such commands based on the known locations and orientations of the substrates A, B in the XY plane as determined by the controller during the fiducial identification process described above. In this manner, the dispensing system 30 may automatically and actively adjust positioning of the first and second applicators 34, 38 while dispensing to correct for local rotation of substrates A and B.

[0062] As shown in FIG. 9, the first applicator 34 and its dispensing tip 94 may be moved by the primary positioner 36 to dispense a second leg 116b of fluid pattern 116. Simultaneously, the second applicator 38 and its dispensing tip 96 may be moved by the secondary positioner 40 relative to the primary positioner 36 and the first applicator 34 to dispense a second leg 118b of fluid

pattern 118. More specifically, the controller may command the primary positioner 36 to execute x_1 and y_1 movements, and further command the secondary positioner 40 to simultaneously execute corrective x_2 and y_2 movements relative to the primary positioner 36 while dispensing to correct for the local rotation of substrates A and B.

[0063] As shown in FIG. 10, the first applicator 34 and its dispensing tip 94 may be moved by the primary positioner 36 to dispense a third leg 116c of fluid pattern 116. Simultaneously, the second applicator 38 and its dispensing tip 96 may be moved by the secondary positioner 40 relative to the primary positioner 36 and the first applicator 34 to dispense a third leg 118c of fluid pattern 118. More specifically, and as similarly performed when dispensing the first legs 116a, 118a, the controller may command the primary positioner 36 to execute x_1 and y_1 movements, and simultaneously the controller may command the secondary positioner 40 to execute corrective x_2 and y_2 movements relative to the primary positioner 36 to correct for the local rotation of substrates A and B.

[0064] As shown in FIG. 11, the first applicator 34 and its dispensing tip 94 may be moved by the primary positioner 36 to dispense a fourth leg 116d of fluid pattern 116. Simultaneously, the second applicator 38 and its dispensing tip 96 may be moved by the secondary positioner 40 relative to the primary positioner 36 and the first applicator 34 to dispense a fourth leg 118d of fluid pattern 118, thereby completing the fluid patterns 116, 118. More specifically, and as similarly performed when dispensing the second legs 116b, 118b, the controller may command the primary positioner 36 to execute x_1 and y_1 movements, and simultaneously the controller may command the secondary positioner 40 to execute corrective x_2 and y_2 movements relative to the primary positioner 36 to correct for the local rotation of substrates A and B.

[0065] One or both of the substrates A, B may be tilted relative to the XY plane, as demonstrated by substrate 130 in FIG. 12A. As described above, the height sensor 114 may be operated to collect multiple height measurements of a tilted substrate along the Z axis, and these measurements may then be conveyed to the controller via a sensor output signal. Alternatively, as described above, these Z height measurements may be read into the controller from an electronic data file made available by the user. As shown in FIG. 12A, the controller may then determine a dispense height path P that varies in height

along the Z axis and along which a corresponding dispensing tip 94, 96 may be moved in order to maintain a constant and accurate dispense gap G between the tip 94, 96 and the tilted substrate 130. Thus, if the substrate B of FIGS. 7-11, and its corresponding component 120b, had a tilt like that shown for substrate 130, in addition to making the x_2 and y_2 corrections as described above, the secondary positioner 40 would make corrective z_2 movements relative to the primary positioner 36, while dispensing, to correct for the tilt of substrate B with respect to substrate A. In this manner, the system 30 may accurately dispense a fluid pattern, such as pattern 118, onto the tilted substrate. Consequently, as shown in FIG. 12A, corrective z_2 movements would be made along the Z axis such that the dispensing tip 96 travels in a plane substantially parallel to the tilted substrate.

[0066] A similar process may be performed where one or both of the substrates A, B is contoured relative to the XY plane, along the Z axis, as demonstrated by substrate 132 in FIG. 12B, which could be a warped substrate, for example. In particular, the system may collect multiple Z height measurements corresponding to a contoured substrate, or otherwise read the Z height measurements from an electronic data file. As shown in FIG. 12B, the system 30 may then determine a corresponding dispense height path P that varies in height along the Z axis and along which a corresponding dispensing tip 94, 96 may be moved in order to maintain a constant and accurate dispense gap G between the tip 94, 96 and the contoured substrate 132. The process described above with respect to the tilted substrate shown in FIG. 12A may also be applied to contoured substrates. For example, if the substrate B shown in Figs. 7-11 had a contour like that shown for substrate 132, in addition to making the x_2 and y_2 corrections as described above, the secondary positioner 40 would also make corrective z_2 movements relative to the primary positioner 36, while dispensing, to correct for the contour of substrate B with respect to substrate A. In this manner, the system 30 may accurately dispense a fluid pattern, such as fluid pattern 118, onto the contoured substrate. Consequently, as shown in FIG. 12B, corrective z_2 movements would be made along the Z axis such that the dispensing tip 96 travels along a path that substantially conforms to the contoured substrate.

[0067] As demonstrated by exemplary substrates 134 and 136 in FIG. 13A, two substrates being dispensed upon, for example substrates A and B,

may each be uniquely tilted and contoured relative to the XY plane and relative to each other. Corresponding dispense height paths P1 and P2 may be determined by the system 30 based on the Z height measurements referenced by the system controller. In particular, as described above, a height sensor may collect multiple height measurements for each of the substrates 134, 136 and generate a sensor output signal that communicates these height measurements to the system controller. In another embodiment, the height measurements defining the tilt and/or contour of a substrate may be provided by electronic data that is entered into the system 30, or otherwise made available to the system 30, by a user. Such electronic data may then be used to determine a dispense height path.

[0068] In another embodiment (not shown), first and second substrates may be arranged such that they are not rotated relative to each other in the XY plane, and each substrate is provided with the same tilt and/or contour relative to the XY plane such that the substrates are not uniquely tilted or contoured relative to each other. In such case, the dispense height paths determined by the system 30 for the substrates may be substantially identical, and the secondary positioner 40 need not make corrective movements relative to the primary positioner 36 during dispense. In other words, the first and second applicators may remain stationary relative to each other while being moved together along X, Y, and Z by the primary positioner to simultaneously dispense on the first and second substrates.

[0069] With reference to substrates A and B of FIGS. 6-11, a first exemplary scenario, also described above, may arise in which substrate A is generally planar and lies parallel to the XY plane, and substrate B is tilted relative to the XY plane and/or includes a contoured surface, as demonstrated by substrates 130 and 132 of FIGS. 12A and 12B. In such case, the controller may determine a dispense height path for tilted and/or contoured substrate B based on height measurements collected during the height sensing operation discussed above. Then, while the first applicator 34 is moved in the XY plane to dispense onto substrate A and the second applicator 38 is simultaneously moved in the XY plane to dispense onto substrate B, the controller may command the secondary positioner 40 to simultaneously execute z_2 movements relative to the primary positioner 36. Thereby, the second dispensing tip 96 is movable along the pre-determined dispense height path while the second

applicator 38 dispenses onto tilted and/or contoured substrate B. In this manner, the dispensing system 30 may automatically and actively adjust the positioning of the second applicator 38 along the Z axis to correct for tilt and/or contour of substrate B relative to the XY plane.

[0070] In a second exemplary scenario, substrate A may be tilted and/or contoured relative to the XY plane, as demonstrated by substrates 130 and 132 of FIGS. 12A and 12B, while substrate B is generally planar and lies parallel to the XY plane. In such case, the controller may determine a dispense height path for tilted and/or contoured substrate A in a manner as described above. Then, while the first applicator 34 is moved in the XY plane to dispense onto tilted and/or contoured substrate A, the controller may command the primary positioner 36 to simultaneously execute z_1 movements. Thereby, the first dispensing tip 94 is movable along the pre-determined dispense height path while the first applicator 34 dispenses onto tilted and/or contoured substrate A. Simultaneously, the second applicator 38 is moved in the XY plane to dispense onto substrate B, and the controller may command the secondary positioner 40 to execute z_2 movements relative to the primary positioner 36, the z_2 movements being substantially opposite of the z_1 movements made by the primary positioner 36. Thereby, the second dispensing tip 96 may be maintained at a constant, pre-determined dispense height corresponding to substrate B while the second applicator 38 dispenses onto part B.

[0071] In a third exemplary scenario, both substrates A and B may be tilted and/or contoured relative to the XY plane. By way of example with reference to FIG. 13A, substrate A may correspond to substrate 134 and substrate B may correspond to substrate 136. In this regard, substrate A may be provided with a first tilt and/or a first contour that is unique to substrate A, and substrate B may be provided with a second tilt and/or a second contour that is unique to substrate B. The controller may determine a first dispense height path P1 corresponding to tilted and/or contoured substrate A and a second dispense height path P2 corresponding to tilted and/or contoured substrate B, in a manner as described above. Then, while the first applicator 34 is moved in the XY plane to dispense onto substrate A, the controller may command the primary positioner 36 to simultaneously execute z_1 movements. Thereby, the first dispensing tip 94 is movable along the first dispense height path P1 to maintain a first dispense gap G1, while the first applicator 34 dispenses onto

substrate A. Simultaneously, while the second applicator 38 is moved in the XY plane to dispense onto tilted and/or contoured substrate B, the controller may command the secondary positioner 40 to execute z_2 movements relative to the primary positioner 36 to correct both for the z_1 movements executed by the primary positioner 36 and the unique tilt and/or contour of substrate B.

Thereby, the second dispensing tip 96 is movable along the second dispense height path P2 to maintain a second dispense gap G2, while the second applicator 38 dispenses onto substrate B. In this manner, the first applicator 34 may accurately dispense onto a uniquely tilted and/or contoured first substrate and simultaneously the second applicator 38 may accurately dispense onto a uniquely tilted and/or contoured second substrate.

[0072] In an alternative exemplary embodiment similar to the third exemplary scenario described above, the first and second applicators 34, 38 may simultaneously dispense first and second fluid patterns at first and second dispense regions, respectively, that are each distinct regions of a single common substrate. For example, as shown in FIG. 13B, the primary positioner 36 may execute z_1 movements to move the first applicator 34 along a first dispense height path P1 at a first uniquely contoured dispense region of substrate 138. Thereby, a first dispense gap G1 associated with the first dispense region may be maintained while dispensing. Simultaneously, the secondary positioner 40 may execute z_2 movements to move the second applicator 38 along a second dispense height path P2 at a second uniquely contoured dispense region of the substrate 138. Thereby, a second dispense gap G2 associated with the second dispense region may be maintained while dispensing. In various embodiments, the first and second dispense gaps G1, G2 may be the same or they may be different.

[0073] In a fourth exemplary scenario, substrates A and B may both be generally planar and lie parallel to the XY plane but positioned at different distances along the Z axis relative to the XY plane. For example, substrate A may lie in the XY plane, while substrate B is spaced above the XY plane. In such case, neither substrate A nor B is tilted or contoured relative to the XY plane, and thus active correction along the Z axis during dispense is not required by either applicator 34, 38. The controller may determine an appropriate dispense height for each substrate A, B in the manner described above. Prior to dispensing, the controller may command the primary positioner

36 to execute z_1 movement to lower the first dispensing tip 94 to its corresponding dispense height along the Z axis above substrate A. Simultaneously, the controller may command the secondary positioner 40 to execute z_2 movement relative to the primary positioner 36 to lower the second dispensing tip 96 to its corresponding dispense height along the Z axis above substrate B. The controller may then command the primary positioner 36 to move the first and second applicators 34, 38 together in the XY plane so that they may simultaneously dispense first and second fluid patterns onto substrates A and B, respectively, while maintaining the corresponding dispense heights for the applicators 34, 38.

[0074] In view of the disclosure above, persons of ordinary skill in the art will appreciate that the dispensing system 30 is capable of executing x_1 , y_1 , and z_1 movements with the primary positioner 36 and simultaneously executing x_2 , y_2 , and z_2 movements with the secondary positioner 40. Moreover, these movements are executable while the first applicator 34 dispenses at a first dispense region, such as a first substrate, and the second applicator 38 simultaneously dispenses at a second dispense region, such as a second substrate. In this manner, the dispensing system 30 is controllable to automatically and actively adjust positioning of the first and second applicators 34, 38 while dispensing to correct for misalignment of first and second substrates being dispensed upon.

[0075] FIGS. 14A and 14B present a flow diagram illustrating steps of a method 200 according to one embodiment of the invention for simultaneously dispensing at first and second dispense regions in a manner consistent with the disclosure above. The method 200 may be performed with dispensing system 30 or any suitable variation thereof, for example. The referenced dispense regions are denoted "DR." As described above, the first and second dispense regions may be first and second substrates, or they may be distinct first and second regions of a single substrate, such as a panelized circuit board. The referenced first and second applicators are denoted "A1" and "A2," and may be mounted to and movable by primary and secondary positioners, respectively, such as positioners 36 and 40 of dispensing system 30 disclosed above.

[0076] At step 202, the dispensing system first identifies reference fiducials associated with each of the plurality of dispense regions, for example in the manner described above. In one embodiment, each dispense region may

be provided with its own set of corresponding reference fiducials. In another embodiment, multiple dispense regions may be associated with a single set of reference fiducials, for example where the dispense regions are regions of a single substrate. At step 204, the system then determines the location and orientation (i.e., the position) of each dispense location in the XY plane defined by the system, based on the identified reference fiducials.

[0077] At step 206, the system then collects Z height measurements for the dispense regions through height sensing. As described above, such height sensing may include using a height sensor to collect multiple height measurements for dispense regions that are tilted and/or contoured relative to the XY plane. For example, such height sensing may include collecting multiple height measurements of a path along which fluid is to be dispensed, the path encompassed by a dispense region. The height sensor may then generate a sensor output signal that communicates the height measurements to the system controller.

[0078] Alternatively, as described above, the height measurements may be collected by reading them into the system controller from an electronic data file made available by a user, such as a surface contour data file for example. Accordingly, at step 206, the user may be prompted by a graphical user interface of the dispensing system to identify the source of the Z height information to be used by the dispensing system. In response to the prompt, the user may indicate that the Z height information will be provided by an electronic data file made available to the system controller, which file may then be identified by the user, or that the Z height information should be determined by the dispensing system through collection of Z height measurements using a height sensor, as described above.

[0079] At step 208, the system may select first and second dispense regions from the plurality of dispense regions, and assign a first applicator A1 for dispensing a first fluid pattern at the first dispense region and a second applicator A2 for dispensing a second fluid pattern at the second dispense region.

[0080] At step 210, the system then assesses, for each of the selected first and second dispense regions, whether the dispense region is tilted and/or contoured relative to the XY plane, along the Z axis. If the dispense region is not tilted or contoured, the system may proceed to step 212 and determine a

proper dispense height for the applicator assigned to the dispense region, based on a single Z height previously measured for the dispense region, as described above. Alternatively, at step 214, where the dispense region is tilted and/or contoured relative to the XY plane, the system may determine a corresponding dispense height path based on multiple Z heights that were previously measured with a height sensor or otherwise provided by external data entered by a user, as described above. For example, where each dispense region is uniquely tilted and/or contoured (see FIGS. 13A and 13B), the system may determine a unique dispense height path corresponding to each dispense region. At step 216, the system may then adjust, as appropriate, the control algorithms associated with an applicator assigned to a tilted and/or contoured dispense region to account for tilt and/or contour of the surface that will be dispensed upon. For example, the control algorithms, including controller output signals, for an applicator assigned to a tilted and/or contoured dispense region may be adjusted so that the applicator selectively dispenses fluid from a proper height or heights dependent on the dispense height path while moving in directions having X and Y components of movement, to dispense a fluid pattern.

[0081] At steps 218a and 218b, the system positions the first applicator in the XY plane above a first dispense site at the first dispense region. Simultaneously, the system may move the second applicator relative to the first applicator in the XY plane to position the second applicator above a first dispense site at the second dispense region. At step 220, the system then simultaneously lowers the first and second applicators along the Z axis to their respective dispense heights, as determined above in steps 210-214. If a dispense region is tilted and/or contoured, its applicator may be lowered to an initial dispense height positioned within the dispense height path. At step 222, the first and second applicators are controlled to start dispensing fluid at the respective dispense regions positioned below.

[0082] Starting at step 224, the first and second applicators are moved along the X, Y, and/or Z axes, based on controller output signals provided by the system controller, to dispense the first and second fluid patterns, respectively, according to whether either of the first and second dispense regions is tilted and/or contoured relative to the XY plane, and/or rotated in the XY plane relative to the other dispense region (i.e., locally rotated). At step

226, if neither dispense region is tilted or contoured and there is no local rotation, the system may proceed to step 228 and move the first and second applicators together in the XY plane to dispense the first and second fluid patterns. For example, such may be accomplished with the primary positioner 36 of dispensing system 30 through x_1 and y_1 movements. Through step 228, the second applicator need not be moved relative to the first applicator while dispensing, because the dispense regions are neither tilted nor contoured relative to the XY plane, nor rotated relative to each other in the XY plane. In alternative to step 228, if the dispense regions are rotated relative to each other in the XY plane, the system proceeds to steps 230a and 230b. At steps 230a and 230b, the system moves the first applicator in the XY plane, for example with primary positioner 36, to dispense the first fluid pattern at the first dispense region. Simultaneously, the system moves the second applicator relative to the first applicator in the XY plane, for example with secondary positioner 40, to dispense the second fluid pattern at the second dispense region. Thereby, the system may actively correct for local rotation while dispensing.

[0083] In an alternative to step 226, if the first dispense region and/or the second dispense region is tilted and/or contoured relative to the XY plane, the system may proceed to step 232. Through step 232, the system moves the first and second applicators according to whether the first and second dispense regions are rotated relative to each other in the XY plane (i.e., locally rotated). If the dispense regions are not locally rotated, the system may proceed to steps 234a and 234b. At steps 234a and 234b, the system may move the first and second applicators together in the XY plane, as indicated in step 234a, for example with primary positioner 36, to dispense the first and second fluid patterns without relative movement between the applicators in XY. Simultaneously, as indicated in step 234b, the system may move the first applicator and/or the second applicator in Z along a corresponding dispense height path (determined in step 214) to account for tilt and/or contour of a corresponding dispense region relative to the XY plane.

[0084] For example, during dispense, the second applicator may be moved in Z relative to the first applicator according to a first controller output signal representative of a tilt and/or contour of one of the dispense regions. Where both of the dispense regions are uniquely tilted and/or contoured in Z, the first and second applicators may be moved independently in Z during

dispense according to a first controller output signal representative of a first tilt and/or contour of one of the dispense regions, and a second controller output signal representative of a second tilt and/or contour of the other of the dispense regions.

[0085] In alternative to steps 234a and 234b, if the dispense regions are locally rotated in addition to at least one of them being tilted and/or contoured, the system may proceed to steps 236a, 236b, and 236c. At step 236a, the first applicator is moved in the XY plane, for example with primary positioner 36, to dispense the first fluid pattern at the first dispense region. Simultaneously, at step 236b, the second applicator is moved relative to the first applicator in the XY plane, for example with secondary positioner 40, to dispense the second fluid pattern at the second dispense region. Simultaneously, at step 236c, the first applicator and/or the second applicator is moved in Z along a corresponding dispense height path to account for tilt and/or contour of a corresponding dispense region relative to the XY plane.

[0086] At step 238, upon completion of dispensing the first and second fluid patterns, the first and second applicators may be raised back up along the Z axis to their pre-dispense heights, for example. At step 240, the system may evaluate whether there are additional fluid patterns to be dispensed, for example at third and fourth dispense regions. If there remains additional dispensing to be performed, the system may return to step 208, as indicated by symbol B. If all dispensing is complete, the system may end its dispensing operations.

[0087] Methods of dispensing have been described above in connection with specified orientations of first and second dispense regions and corresponding movements of first and second applicators for simultaneously dispensing at the first and second dispense regions. However, persons skilled in the art will appreciate that the methods described may be adapted as appropriate to simultaneously dispense at any two dispense regions. For example, where the first dispense region and/or the second dispense region is uniquely tilted and/or contoured relative to the XY plane, the system may move the first applicator and the second applicator independently along X, Y, and/or Z while dispensing to simultaneously dispense a first fluid pattern at the first dispense region and a second fluid pattern at the second dispense region.

[0088] Referring to FIGS. 15 and 16, a secondary positioner 300 according to another exemplary embodiment of the invention is shown. It will be understood that like reference numerals refer to like features shown in FIGS. 4-6, such as features of the primary positioner 36 for example. In this embodiment, the primary positioner 36 is shifted 90 degrees in the XY plane relative to its orientation shown in the embodiment of FIGS. 4-6. As such, the support 48 is aligned with the X axis and thus serves as an x_1 support. Similarly, though not shown, the supports 44a and 44b are aligned with the Y axis and thus serve as y_1 supports. It will be understood that the primary positioner 36 may be provided in any desired orientation relative to the global X, Y, and Z axes, and further that the scope of the invention is not limited to the exemplary orientations shown and described herein.

[0089] General similarities and differences between the secondary positioner 300 and the secondary positioner 40 will now be described, followed by a description of the structural features of the secondary positioner 300.

[0090] Similar to the secondary positioner 40, the secondary positioner 300 is mounted to and supported by the primary positioner 36, via z_1 carriage 60, such that the primary positioner 36 moves both of the first and second applicators 34, 38 in X, Y, and Z simultaneously, as indicated by x_1 , y_1 , and z_1 . Moreover, similar to the secondary positioner 40, the secondary positioner 300 operates to provide automated relative movement between the first and second applicators 34, 38 in X, Y, and Z, as indicated by x_2 , y_2 , and z_2 . Accordingly, similar to the secondary positioner 40, the secondary positioner 300, in combination with the primary positioner 36, enables simultaneous independent positional control for each of the first applicator 34 and the second applicator 38 in the X, Y, and Z axes.

[0091] As described above, the secondary positioner 40 provides automated positional adjustments of the first and second applicators 34, 38 relative to one another by moving the second applicator 38 relative to the first applicator 34 in all three axes (X, Y, and Z, as indicated by x_2 , y_2 , and z_2 in FIG. 5). In contrast, the secondary positioner 300 provides these automated positional adjustments by moving the second applicator 38 relative to the first applicator 34 in two of the axes (i.e., Y and Z, as indicated by y_2 and z_2 in FIGS. 15 and 16), and by moving the first applicator 34 relative to the second

applicator 38 in the remaining axis (i.e., X, as indicated by x_2 in FIGS. 15 and 16).

[0092] Unlike the secondary positioner 40, the secondary positioner 300 carries both applicators 34 and 38, as described in greater detail below. Moreover, movement of the first applicator 34 in X is achieved by both the primary positioner 36, as indicated by x_1 , as well as by the secondary positioner 300, as indicated by x_2 . In other words, unlike the secondary positioner 40, the secondary positioner 300 enables automated positional adjustments of the first applicator 34 relative to the primary positioner 36, including the z_1 carriage 60, while the second applicator 38 remains fixed in X relative to the z_1 carriage 60. As such, with respect to the secondary positioner 300, movements in X of the second applicator 38 are controlled entirely by the primary positioner 36.

[0093] The components of the secondary positioner 300 are described below in view of the orientation of the primary positioner 36 relative to the global X, Y, and Z axes. However, as noted above, the primary positioner 36 may be orientated in any suitable manner relative to the X, Y, and Z axes. Accordingly, it will be appreciated that the orientation of the components of the secondary positioner 300, and also those of secondary positioner 40, relative to the global axes may alter depending on the orientation of the primary positioner 36 relative to these axes.

[0094] The secondary positioner 300 includes a mounting bracket 302, or a base plate, that is rigidly mounted to an XZ surface of the z_1 carriage 60 of the primary positioner 36. In this embodiment, the z_1 carriage 60 is in the form of a flat plate, and is slidable along the z_1 bearing guides 58a and 58b, which are disposed on a common XZ outer surface of the z_1 support 56. As best shown in FIG. 16, the mounting bracket 302 is substantially L-shaped and includes a first leg 304 extending in the XZ plane and a second leg 306 extending perpendicularly from the first leg 304 in the YZ plane. The mounting bracket 302 may be mounted to the z_1 carriage 60 via the first leg 304.

[0095] An x_2 movement unit 308 is mounted to the first leg 304 of the mounting bracket 302 and includes oppositely disposed first and second end blocks 310 and 312 that support a linear bearing guide (not shown) extending therebetween along the X axis. An x_2 carriage 314 is carried by the linear bearing guide and is movable in X between the end blocks 310, 312, for moving the first applicator 34 in X relative to the primary positioner 36, as indicated by

x_2 . Movement of the x_2 carriage is powered by a controllable x_2 drive mechanism 316. The first applicator 34 is releasably mounted to a first applicator mount 318, which is coupled to and movable by the x_2 carriage 314.

[0096] A y_2 movement unit 320 is mounted to the second leg 306 of the mounting bracket 302 and is substantially similar in structure and function to the x_2 movement unit 308. In particular, the y_2 movement unit 320 includes oppositely disposed first and second end blocks 322 and 324 that support a linear bearing guide (not shown) extending therebetween along the Y axis. A y_2 carriage 326 is carried by the linear bearing guide and is movable in Y between the end blocks 322, 324 for moving the second applicator 38 in Y relative to the first applicator 34 and the primary positioner 36, as indicated by y_2 . Movement of the y_2 carriage 326 is powered by a controllable y_2 drive mechanism 328.

[0097] A z_2 movement unit 330 is mounted to the y_2 carriage 326 and provides movement of the second applicator 38 in Z relative to the first applicator 34 and the primary positioner 36, as indicated by z_2 . The z_2 movement unit 330 generally includes a primary support bracket 332 and a secondary support bracket 334 movable in Z relative to the primary support bracket 332, each of the brackets 332, 334 being substantially L-shaped, for example. The primary support bracket 332 includes a lower leg 336 extending in the YZ plane and an upper leg 338 extending perpendicularly from the lower leg 336 in the XY plane. The lower leg 336 supports a z_2 base plate 340 on which a pair of z_2 linear bearing guides 342a and 342b, extending along the Z axis, are provided. The upper leg 338 may support a controllable z_2 drive mechanism 344. The secondary support bracket 334 of the z_2 movement unit 330 includes a first leg 346 extending in the YZ plane and a second leg 348 extending perpendicularly from the first leg 346 in the XZ plane. The secondary support bracket 334, via the first leg 346, is supported on a z_2 carriage 350 that is slidable along the z_2 linear bearing guides 342a, 342b, as indicated by z_2 . Movement of the z_2 carriage 350 in Z is powered by the z_2 drive mechanism 344.

[0098] The second applicator 38 is releasably mounted to a second applicator mount 352, which is coupled to a pitch adjustment plate 354 that extends substantially in the XZ plane. In particular, the second applicator mount 352 is selectively coupleable to the pitch adjustment plate 354 at a plurality of positions along a length of the pitch adjustment plate 354. In this

manner, a manual coarse adjustment of a spacing in X between the first and second applicators 34, 38 (i.e., pitch) may be made before dispensing begins. As shown, the second applicator mount 352 may include an upper jaw 356 that slides along an upper edge of the pitch adjustment plate 354 between the plurality of positions, and which may be secured in any one of the positions as desired.

[0099] The pitch adjustment plate 354 is coupled to the second leg 348 of the secondary support bracket 334 of the z_2 movement unit 330. More particularly, the pitch adjustment plate 354 is selectively coupleable to the second leg 348 at a plurality of positions along the length of the pitch adjustment plate 354. Accordingly, a coarse adjustment of the spacing in X, or pitch, between the first and second applicators 34, 38 may be achieved by selectively positioning the second applicator mount 352 relative to the pitch adjustment plate 354, and/or by selectively positioning the pitch adjustment plate 354 relative to the second leg 348 of the secondary support bracket 334.

[00100] The z_2 movement unit 330 may also include features for performing a coarse adjustment of the spacing in Z between the dispensing tips 94, 96 of the first and second applicators 34, 38. For example, in one embodiment the first leg 346 of the secondary support bracket 334 may be selectively coupled to the z_2 carriage 350 at a plurality of positions extending along the Z axis. In other embodiments, the secondary positioner 300 may further include features for performing a coarse adjustment of a spacing in Y between the first and second applicators 34, 38. These coarse adjustments of the applicator spacings in X, Y, and/or Z are performed prior to dispense and may be tailored to a particular dispensing application. Automated fine-tune adjustments of the applicator spacings in X, Y, and/or Z may be performed in real-time during dispense by actuating the x_2 movement unit 308, the y_2 movement unit 320, and/or the z_2 movement unit 330, as described below.

[00101] In one embodiment, the x_2 , y_2 , and z_2 drive mechanisms 316, 328, 344 may each include a stepper motor. Alternatively, the drive mechanisms 316, 328, 344 may include any other suitable electric, pneumatic, or hydraulic drive suitable for movement with a high degree of accuracy, repeatability, and stability. The drive mechanisms 316, 328, 344 may further include mechanical drive elements similar to those described above in connection with drive mechanisms 100a, 100b, 102, 104, 106, 107, and 108. For example, one or

more of the drive mechanisms 316, 328, 344 may include a stepper motor having an output shaft connected with a flexible drive coupling to a rotating lead screw that engages a toothed element provided on the respective carriage 314, 326, 350.

[00102] As described above, the secondary positioner 300 is coupled to the primary positioner 36 such that the x_1 , y_1 , and z_1 movements of the primary positioner 36 are transferred to the secondary positioner 300, and thus to the first and second applicators 34, 38 supported by the secondary positioner 300. Accordingly, and advantageously, the primary positioner 36 may perform primary positional movements of the first and second applicators 34, 38 in X, Y, and Z (x_1 , y_1 , and z_1) relative to the first and second dispense regions being dispensed at, and simultaneously the secondary positioner 40, 300 may perform fine-tune adjustments of the relative spacing between the first and second applicators 34, 38 in X, Y, and Z (x_2 , y_2 , and z_2) during dispense. Moreover, because the primary movements of both of the applicators 34, 38 in X, Y, and Z may be made using only the primary positioner 36, a minimum number of drive mechanisms may be activated during a dispense operation such that control signals provided to the dispensing system 30 during a dispense operation may be most efficient. It will be appreciated that various alternative structural configurations of the primary and secondary positioners 36, 40, 300 are possible, provided that the above-described advantage provided by the primary and secondary positioners 36, 40, 300 is maintained.

[00103] By way of example, where the system 30 is to be controlled to dispense first and second identical fluid patterns at respective first and second dispense regions (e.g., substrates), and where the dispense regions are aligned with one another in the XY plane (i.e., not locally rotated) and neither dispense region is uniquely contoured nor tilted relative to the XY plane, all movements for dispensing may be achieved using only the primary positioner 36. More particularly, any suitable pre-dispense applicator spacing adjustments in X, Y, and/or Z may be made as described above, such that automated x_1 and y_1 movements may accurately position the first and second applicators 34, 38 relative to the their respective dispense regions, and such that automated z_1 movements may accurately position the dispensing tips 94, 96 of the applicators 34, 38 at their respective dispense heights.

[00104] The structural configuration of the secondary positioner 300 offers the additional advantage of minimizing the load carried by the drive mechanism actuating the first movement unit. More particularly, the x_2 drive mechanism 316 is burdened with moving only the x_2 carriage 314, the first applicator 34, and the first applicator mount 318. By comparison, the y_2 drive mechanism 106 of the secondary positioner 40, which corresponds to the x_2 drive mechanism 316 of the secondary positioner 300, is burdened with moving a greater quantity of components, which amount to a greater load. In particular, the y_2 drive mechanism 106 moves the z_2 support 74, the z_2 carriage 78, the x_2 support 80, the second applicator 38, and drive mechanisms 106 and 108, for example.

[00105] Similar to the secondary positioner 40, the secondary positioner 300 enables additional movements x_2 , y_2 , and z_2 relative to the primary positioner 36, which movements may be relatively fine in comparison to the corresponding x_1 , y_1 , and z_1 movements. In other words, the ranges of motion of the secondary positioner 300 may be lesser than the corresponding ranges of motion of the primary positioner 36. Accordingly, the primary positioner 36 may be controlled to perform automated primary movements in X, Y, and/or Z of the first and second applicators 34, 38, together, during dispense. Simultaneously, the secondary positioner 300 may be controlled to perform automated fine-tuning adjustments, during dispense, of the spacings between the first and second applicators 34, 38 in X, Y, and/or Z. In this manner, the first and second applicators 34, 38 may be dynamically positioned to simultaneously dispense respective first and second fluid patterns at respective first and second dispense regions (e.g., first and second substrates). As described above, the dispense regions may be misaligned relative to one another as shown in FIGS. 7-11, and/or at least one of the dispense regions may be tilted and/or contoured relative to the XY plane as shown in FIGS. 12A-13B, for example.

[00106] Additionally, the secondary positioner 300 may be employed to perform the steps of method 200 described above and shown in FIGS. 14A-14B. In this regard, the secondary positioner 300 may further include a camera and a height sensor (not shown), mounted at any suitable locations on the components of the secondary positioner 300. It will be appreciated that certain steps of the method 200 may be performed slightly differently by secondary positioner 300 as compared to when performed by secondary positioner 40,

due to the structural differences between the secondary positioners 40, 300 as described above. For example, when performed by secondary positioner 300, steps 218b, 230b, and 236b include moving the first applicator 34 relative to the second applicator 38 in X, and moving the second applicator 38 relative to the first applicator 34 in Y.

[00107] While the present invention has been illustrated by the description of specific embodiments thereof, and while the embodiments have been described in considerable detail, it is not intended to restrict or in any way limit the scope of the appended claims to such detail. The various features discussed herein may be used alone or in any combination. Additional advantages and modifications will readily appear to those skilled in the art. The invention in its broader aspects is therefore not limited to the specific details, representative apparatus and methods and illustrative examples shown and described. Accordingly, departures may be made from such details without departing from the scope of the general inventive concept.

What is claimed is:

1. A method of dispensing a first fluid pattern at a first dispense region and a second fluid pattern at a second dispense region, the first dispense region and the second dispense region being positioned relative to a reference plane defined by a first axis and a second axis orthogonal to the first axis, the first dispense region being provided with at least one of a first tilt or a first contour relative to the reference plane and along a third axis mutually orthogonal with the first axis and the second axis, the at least one of the first tilt or the first contour being unique to the first dispense region, the method comprising:

determining a first dispense height path corresponding to the at least one of the first tilt or the first contour of the first dispense region, the first dispense height path varying along the third axis and being unique to the first dispense region; and

moving the first applicator along the first dispense height path to dispense the first fluid pattern at the first dispense region, and simultaneously moving the second applicator relative to the second dispense region to dispense the second fluid pattern at the second dispense region.

2. The method of claim 1, further comprising:

collecting multiple height measurements, along the third axis, corresponding to the first dispense region,

wherein determining the first dispense height path includes determining the first dispense height path based on the multiple height measurements.

3. The method of claim 1, wherein the first dispense height path substantially conforms to the at least one of the first tilt or the first contour of the first dispense region such that moving the first applicator along the first dispense height path includes substantially maintaining a first dispense gap between the first applicator and the first dispense region.

4. The method of claim 1, wherein moving the second applicator relative to the second dispense region includes moving the second applicator relative to the first applicator in a direction parallel to the third axis.
5. The method of claim 1, wherein the second dispense region is provided with at least one of a second tilt or a second contour relative to the reference plane and along the third axis, the at least one of the second tilt or the second contour being unique to the second dispense region, the method further comprising:
 - determining a second dispense height path corresponding to the at least one of the second tilt or the second contour of the second dispense region, the second dispense height path varying along the third axis and being unique to the second dispense region,
 - wherein moving the second applicator relative to the second dispense region to dispense the second fluid pattern includes moving the second applicator along the second dispense height path.
6. The method of claim 5, wherein the second dispense height path substantially conforms to the at least one of the second tilt or the second contour of the second dispense region such that moving the second applicator along the second dispense height path includes substantially maintaining a second dispense gap between the second applicator and the second dispense region.
7. The method of claim 1, wherein dispensing the second fluid pattern at the second dispense region includes dispensing a fluid pattern that is substantially identical in size and shape to the first fluid pattern.
8. The method of claim 1, wherein moving the first applicator along the first dispense height path and moving the second applicator relative to the second dispense region include moving the first applicator and the second applicator simultaneously with a common positioner.

9. A dispensing system for dispensing fluid at a first dispense region and a second dispense region, the first dispense region and the second dispense region being positioned relative to a reference plane defined by a first axis and a second axis orthogonal to the first axis, the system comprising:

a first applicator for dispensing fluid at the first dispense region;

a second applicator for dispensing fluid at the second dispense region;

a primary positioner configured to position the first and second applicators for dispensing fluid at the first and second dispense regions, the primary positioner having a first drive that moves the first and second applicators simultaneously in a direction parallel to the first axis, a second drive that moves the first and second applicators simultaneously in a direction parallel to the second axis, and a third drive that moves the first and second applicators simultaneously in a direction parallel to a third axis, the third axis being mutually orthogonal with the first axis and the second axis; and

a secondary positioner being supported by the primary positioner and having a first drive that moves one of the first applicator or the second applicator relative to the other of the first applicator or the second applicator in a direction parallel to the first axis, a second drive that moves one of the first applicator or the second applicator relative to the other of the first applicator or the second applicator in a direction parallel to the second axis, and a third drive that moves one of the first applicator or the second applicator relative to the other of the first applicator or the second applicator in a direction parallel to the third axis,

wherein the third drive of the primary positioner moves the secondary positioner in a direction parallel to the third axis.

10. The dispensing system of claim 9, wherein the secondary positioner is automatically movable with its corresponding drives relative to the primary positioner while the first applicator dispenses fluid at the first dispense region and the second applicator simultaneously dispenses fluid at the second dispense region.

11. The dispensing system of claim 9, wherein the primary positioner is movable with a first range of motion in a direction parallel to the first axis, a second range of motion in a direction parallel to the second axis, and a third range of motion in a direction parallel to the third axis, and the secondary positioner is movable with a first range of motion in a direction parallel to the first axis, a second range of motion in a direction parallel to the second axis, and a third range of motion in a direction parallel to the third axis, and
wherein the first range of motion, the second range of motion, and the third range of motion of the secondary positioner are less than the corresponding first range of motion, second range of motion, and third range of motion of the primary positioner.
12. The dispensing system of claim 9, wherein each of the first drives, each of the second drives, and each of the third drives includes an electrical motor.
13. The dispensing system of claim 9, further comprising:
at least one controller for commanding movement of the primary positioner relative to the first axis, the second axis, and the third axis, and movement of the secondary positioner relative to the first axis, the second axis, and the third axis.
14. The dispensing system of claim 9, wherein the primary positioner further includes a carriage that is moved by the third drive of the primary positioner in a direction parallel to the third axis, the secondary positioner being coupled to the carriage, and wherein movement of the carriage by the third drive moves the first and second applicators in the direction parallel to the third axis.
15. The dispensing system of claim 9, wherein the secondary positioner supports the first applicator and the second applicator.

16. The dispensing system of claim 9, wherein the first drive of the secondary positioner moves the first applicator relative to the second applicator in a direction parallel to the first axis, the second drive of the secondary positioner moves the second applicator relative to the first applicator in a direction parallel to the second axis, and the third drive of the secondary positioner moves the second applicator relative to the first applicator in a direction parallel to the third axis.

17. The dispensing system of claim 9, wherein the primary positioner supports the first applicator and the secondary positioner supports the second applicator.

18. The dispensing system of claim 9, wherein the first, second, and third drives of the secondary positioner move the second applicator relative to the first applicator.

19. A dispensing system for dispensing fluid at first and second dispense regions positioned relative to a reference plane defined by a first axis and a second axis orthogonal to the first axis, the dispensing system comprising:
a first applicator for dispensing a first fluid pattern at the first dispense region;
a second applicator for dispensing a second fluid pattern at the second dispense region;
a first drive that moves the first applicator in a direction parallel to a third axis, the third axis being mutually orthogonal with the first and second axes;
a second drive that moves the second applicator relative to the first applicator in a direction parallel to the third axis; and
a controller operatively coupled with the first and second drives and that identifies at least one of a first tilt or a first contour of the first dispense region relative to the reference plane and generates a controller output signal representative of the first tilt or the first contour,
wherein, in response to the controller output signal, the second drive moves the second applicator relative to the first applicator in a direction parallel to the third axis while the first applicator dispenses the first fluid pattern at the

first dispense region and the second applicator simultaneously dispenses the second fluid pattern at the second dispense region.

20. The dispensing system of claim 19, wherein the at least one of the first tilt or the first contour is identified by the controller based on a plurality of height measurements collected by a height sensor along the third axis and corresponding to the first dispense region, wherein the height sensor generates a sensor output signal representative of the first tilt or the first contour and based on the plurality of height measurements, and the controller output signal is generated in response to the sensor output signal.

21. The dispensing system of claim 19, wherein the at least one of the first tilt or the first contour is identified by the controller based on an electronic data file accessed by the controller, the electronic data file including height measurement information referenced to the third axis and corresponding to the first dispense region, wherein the controller output signal is generated in response to the height measurement information.

22. The dispensing system of claim 19, wherein the controller output signal is a first controller output signal and wherein the controller further identifies at least one of a second tilt or a second contour of the second dispense region relative to the reference plane and generates a second controller output signal representative of the second tilt or the second contour, and wherein, in response to the second controller output signal, the first drive moves the first applicator in a direction parallel to the third axis, while, in response to the first controller output signal, the second drive moves the second applicator relative to the first applicator in a direction parallel to the third axis.

23. The dispensing system of claim 19, wherein the first drive moves the first applicator and the second applicator in a direction parallel to the third axis.

1/16

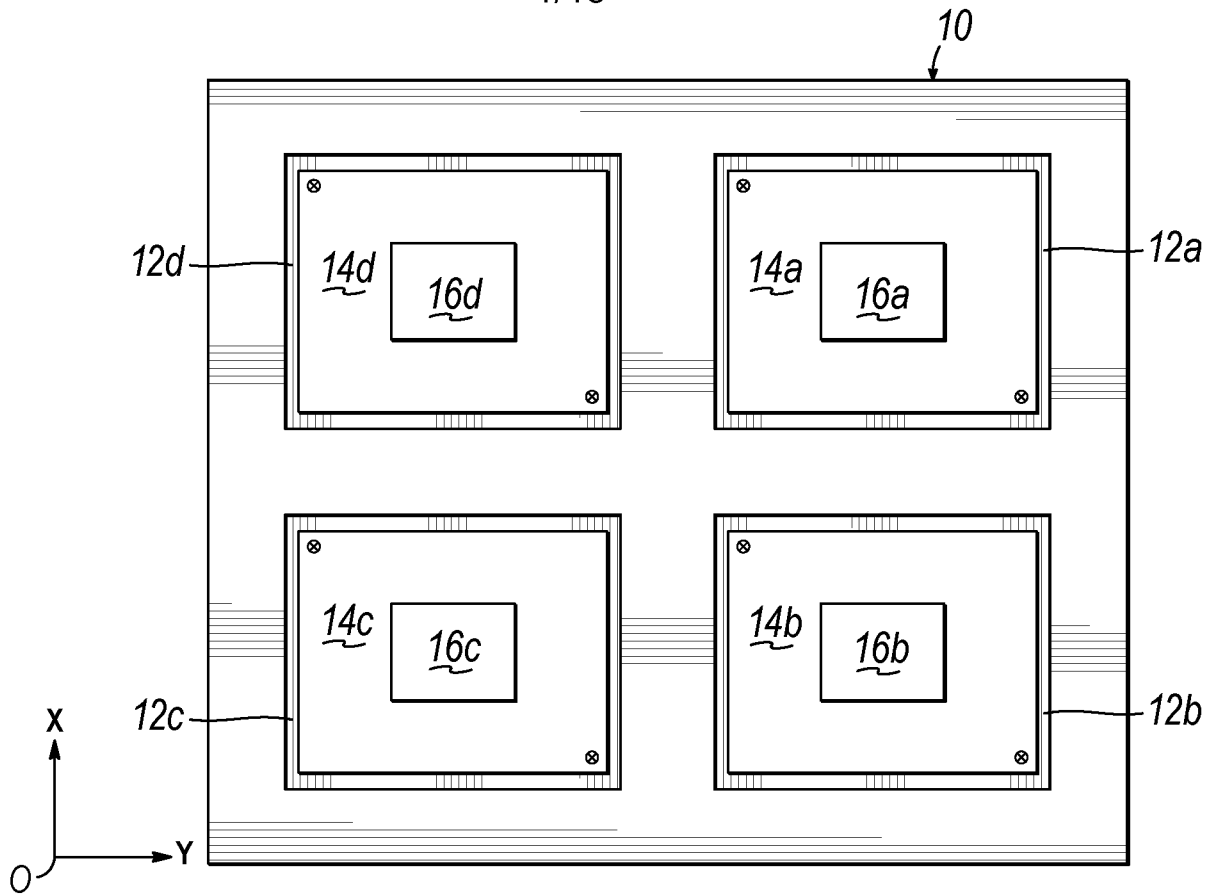


FIG. 1

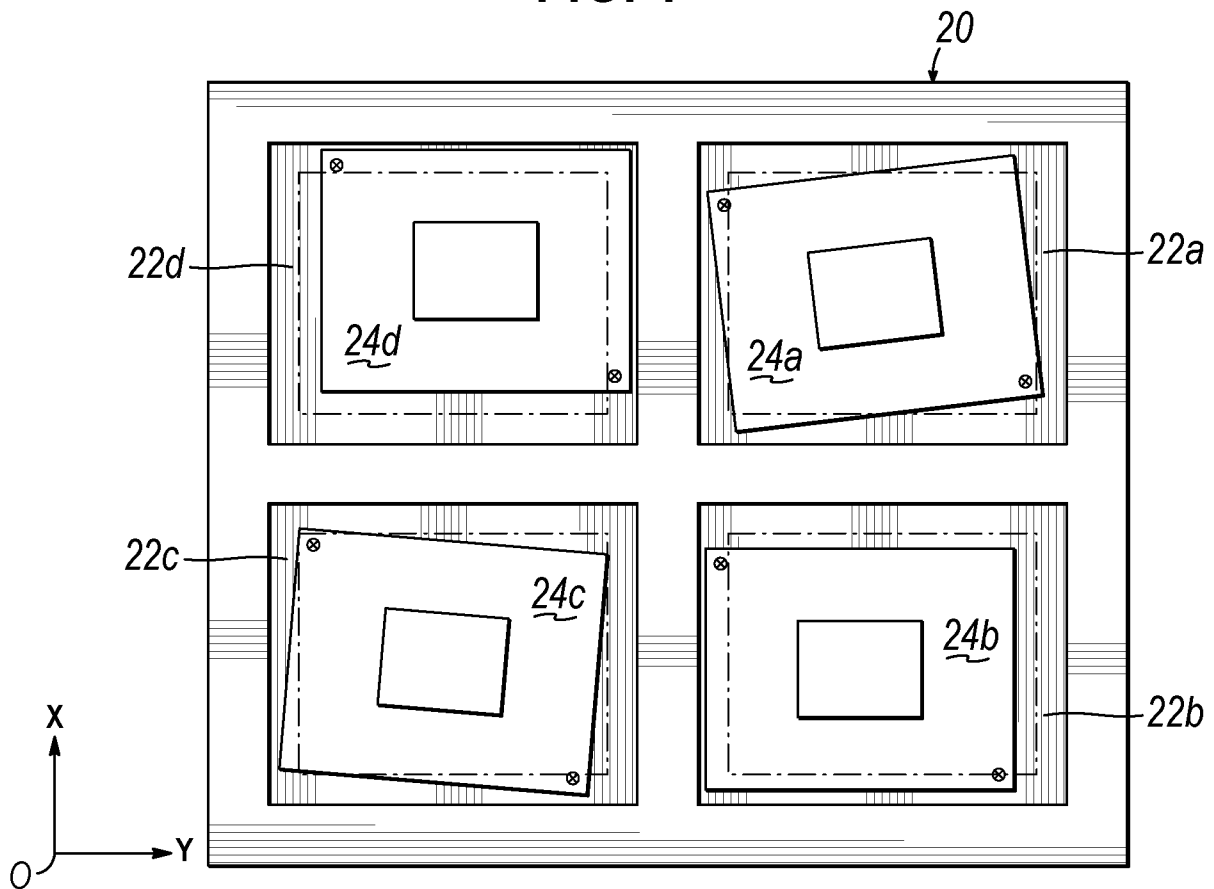


FIG. 2

2/16

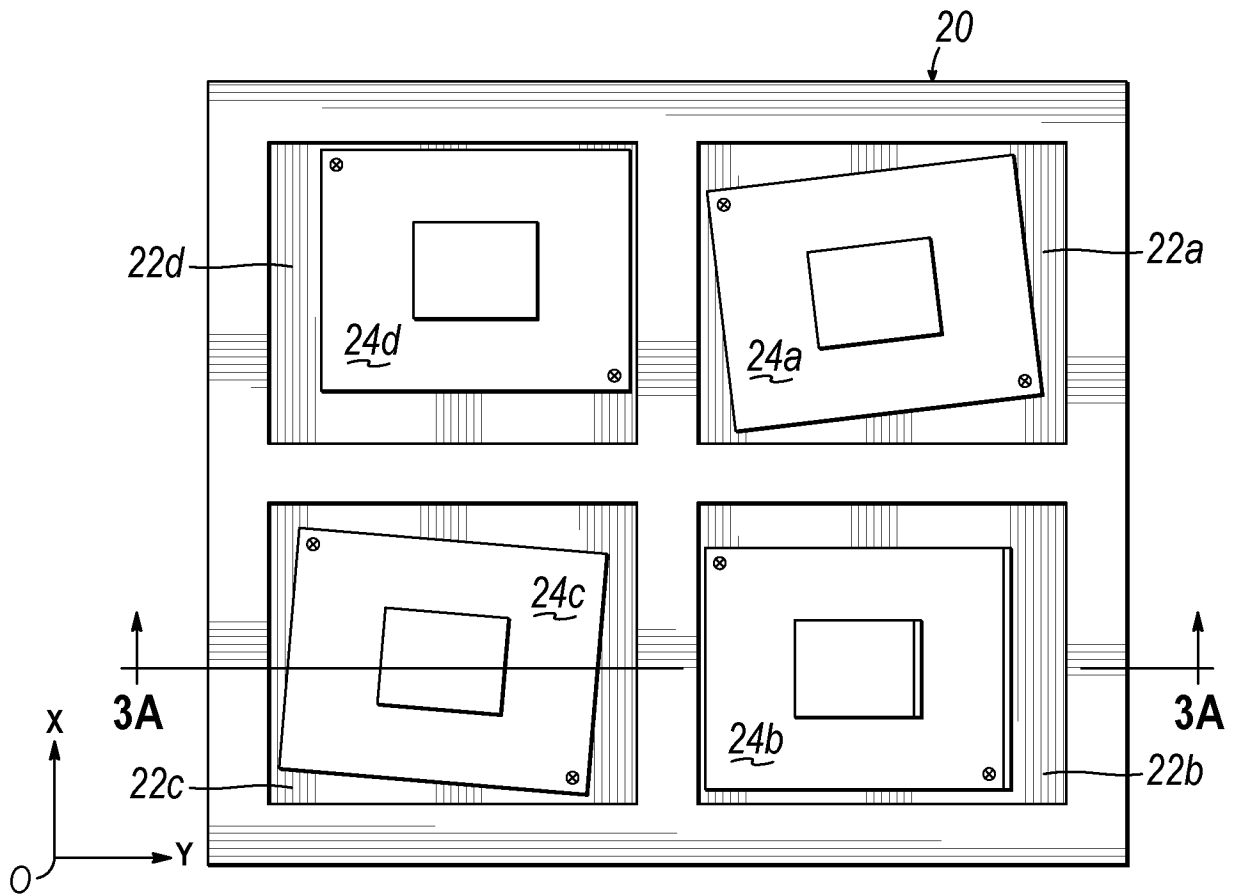


FIG. 3

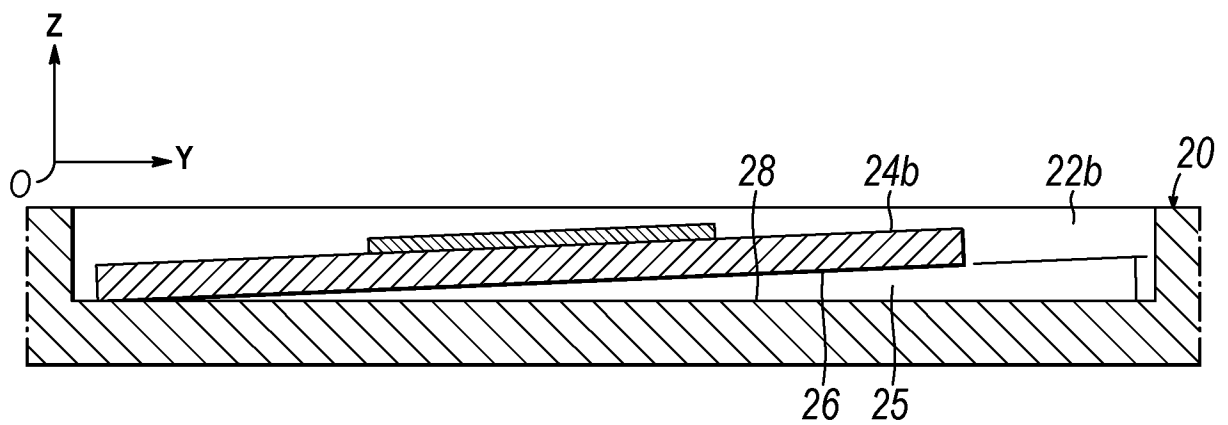


FIG. 3A

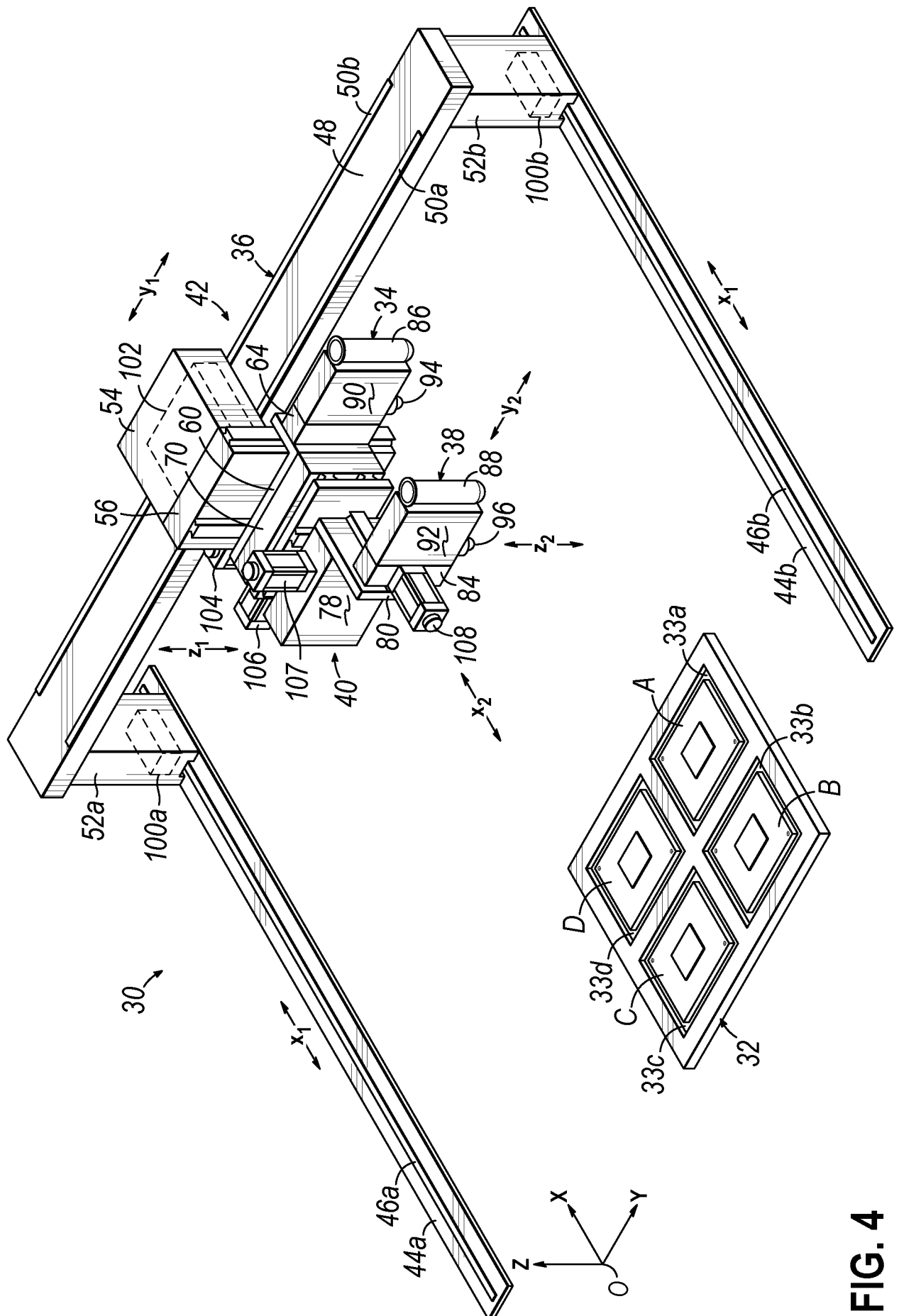


FIG. 4

4/16

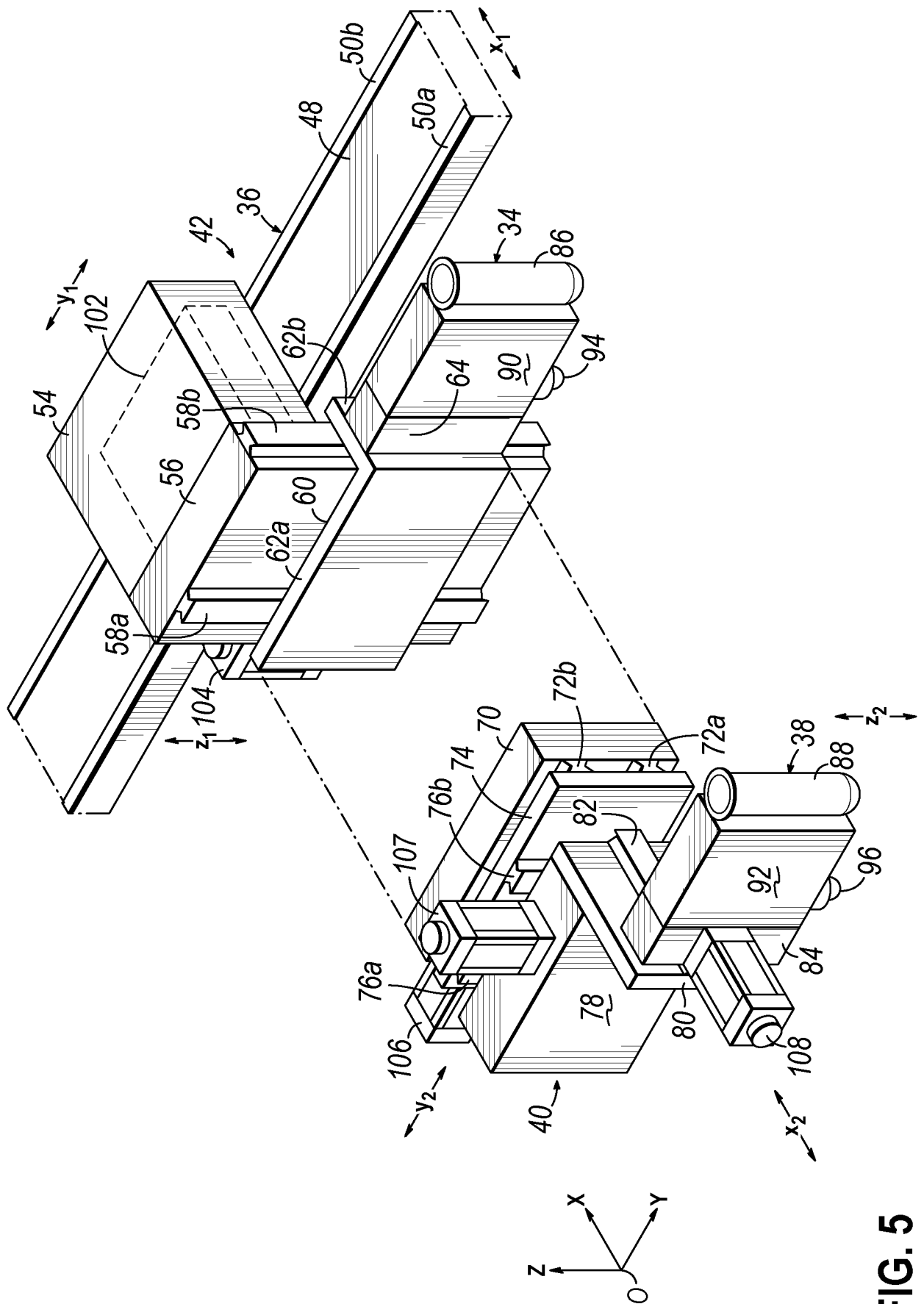


FIG. 5

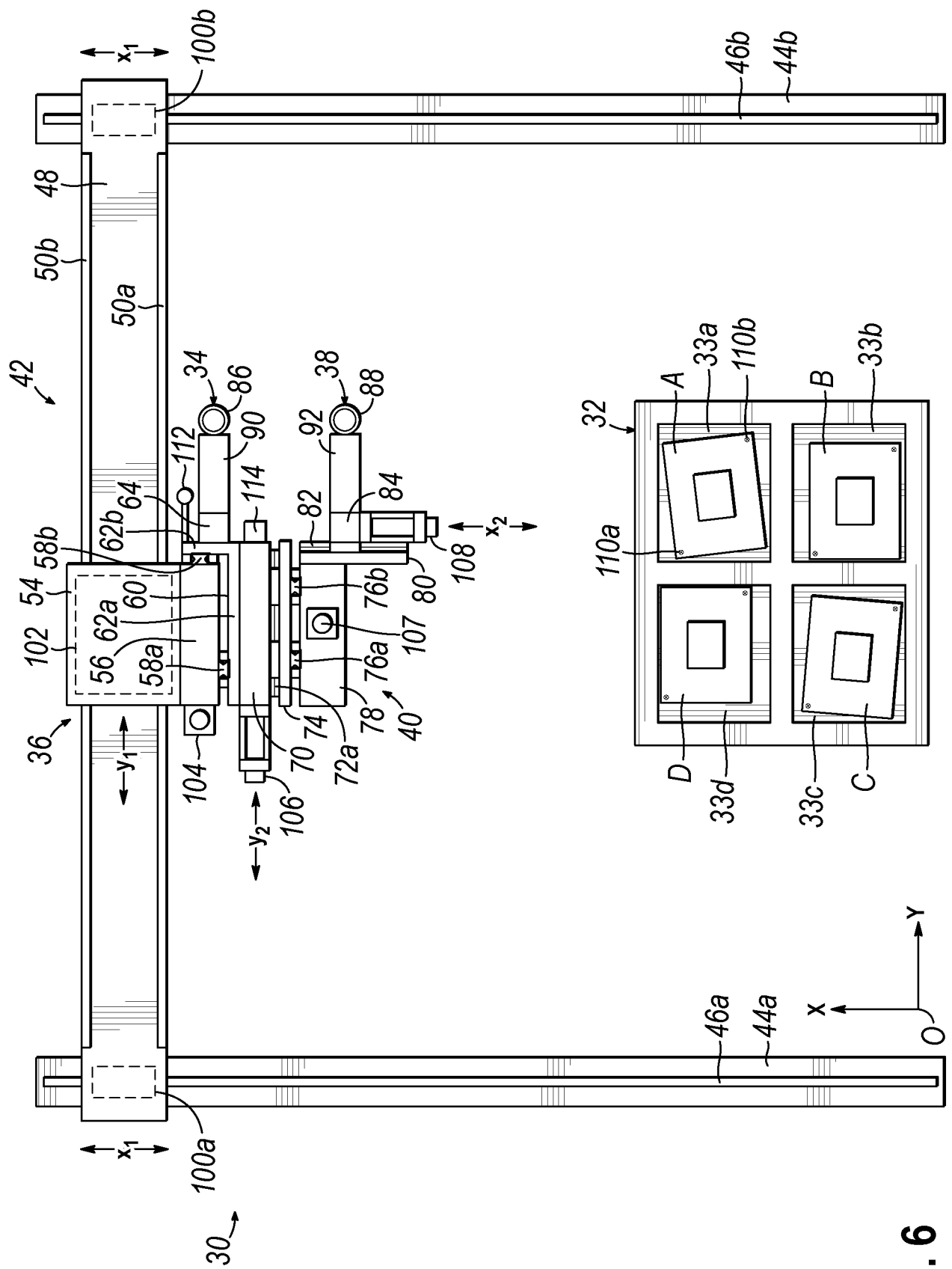


FIG. 6

6/16

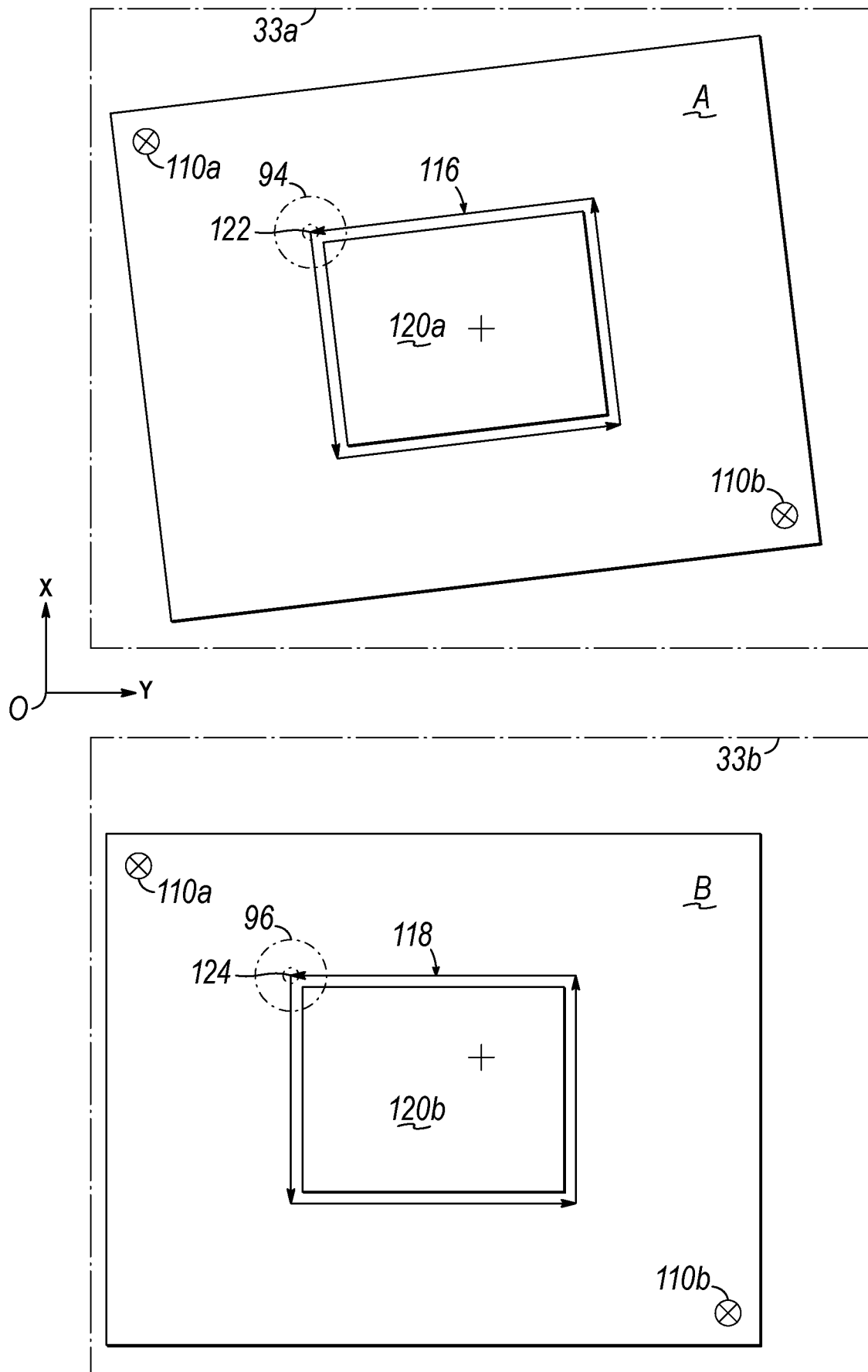


FIG. 7

7/16

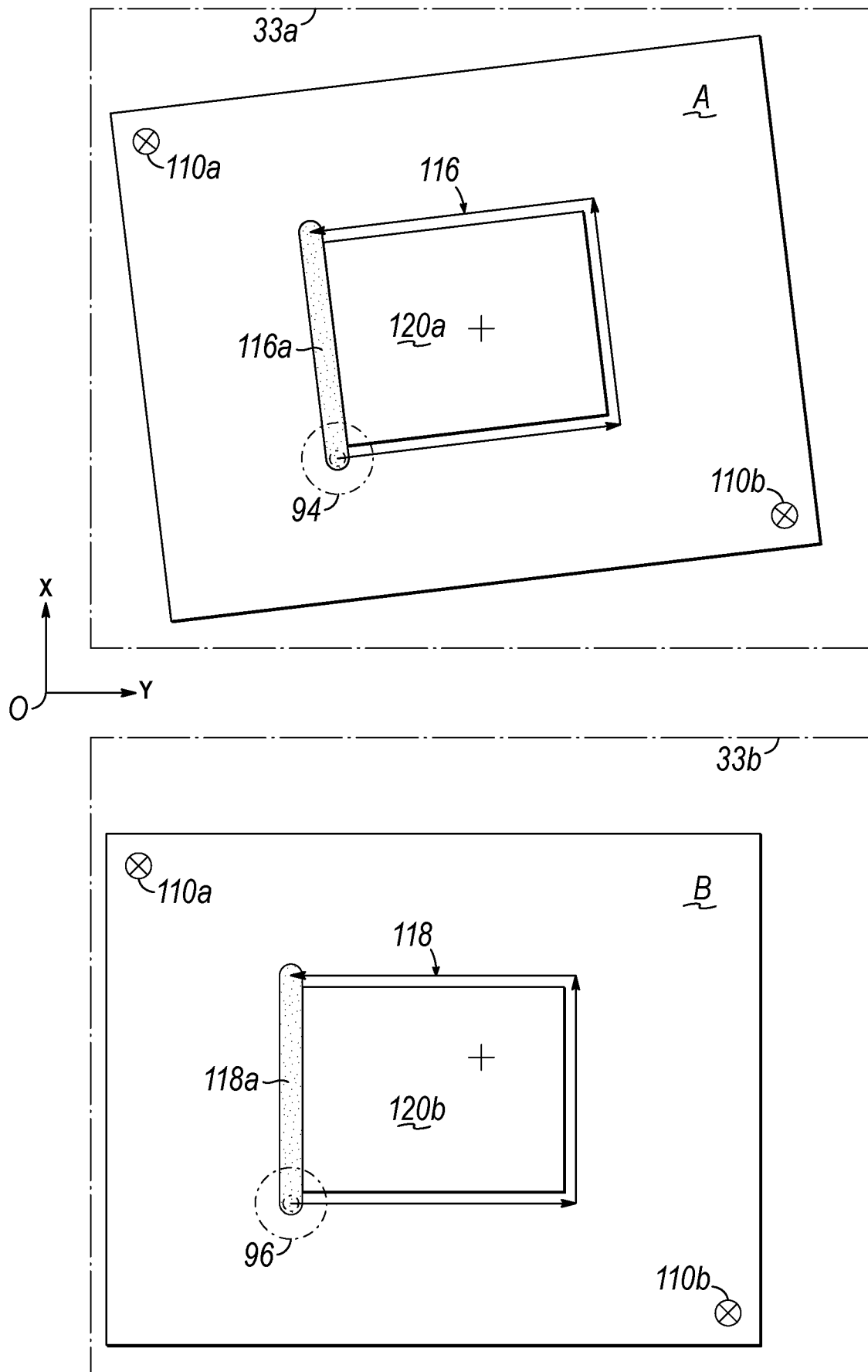


FIG. 8

8/16

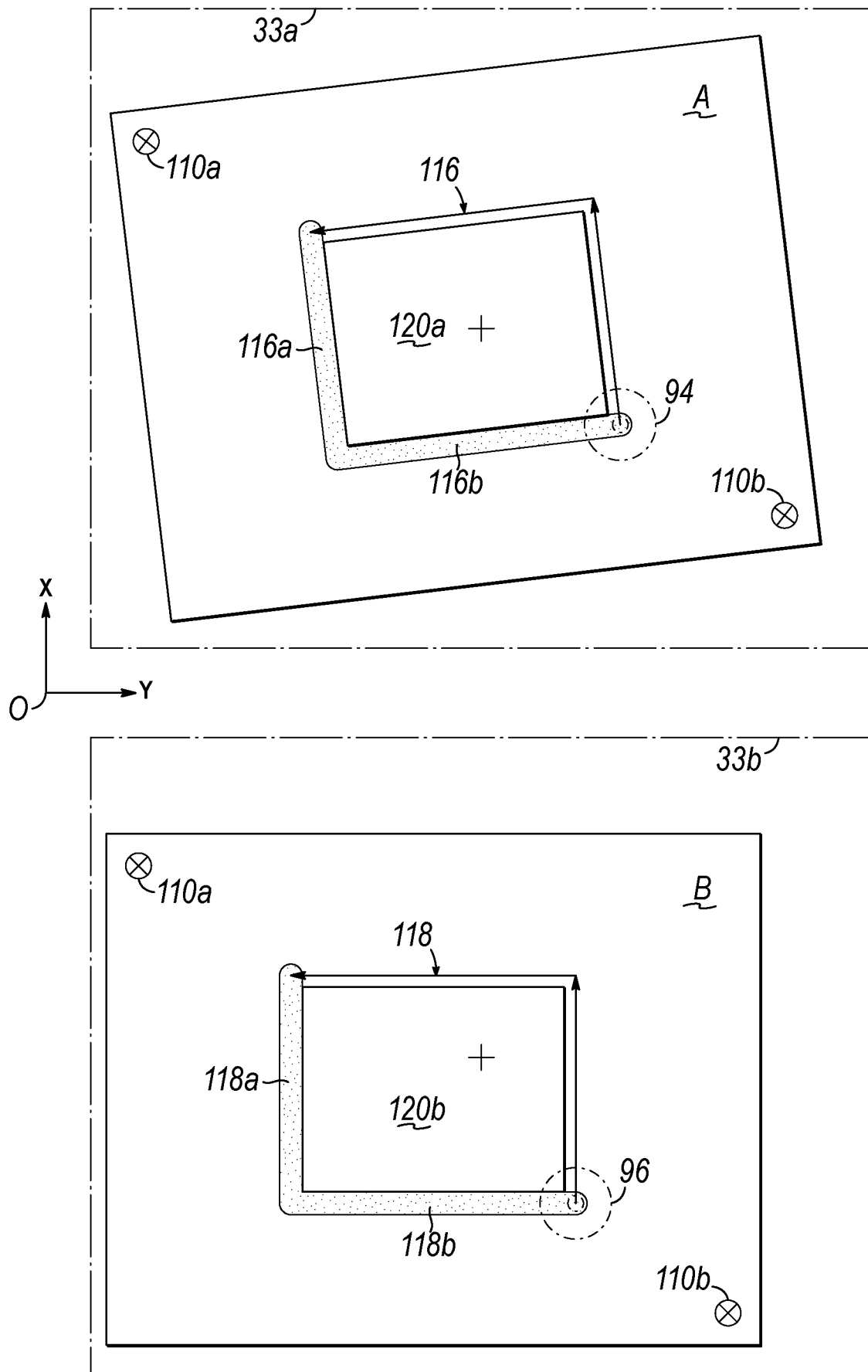


FIG. 9

9/16

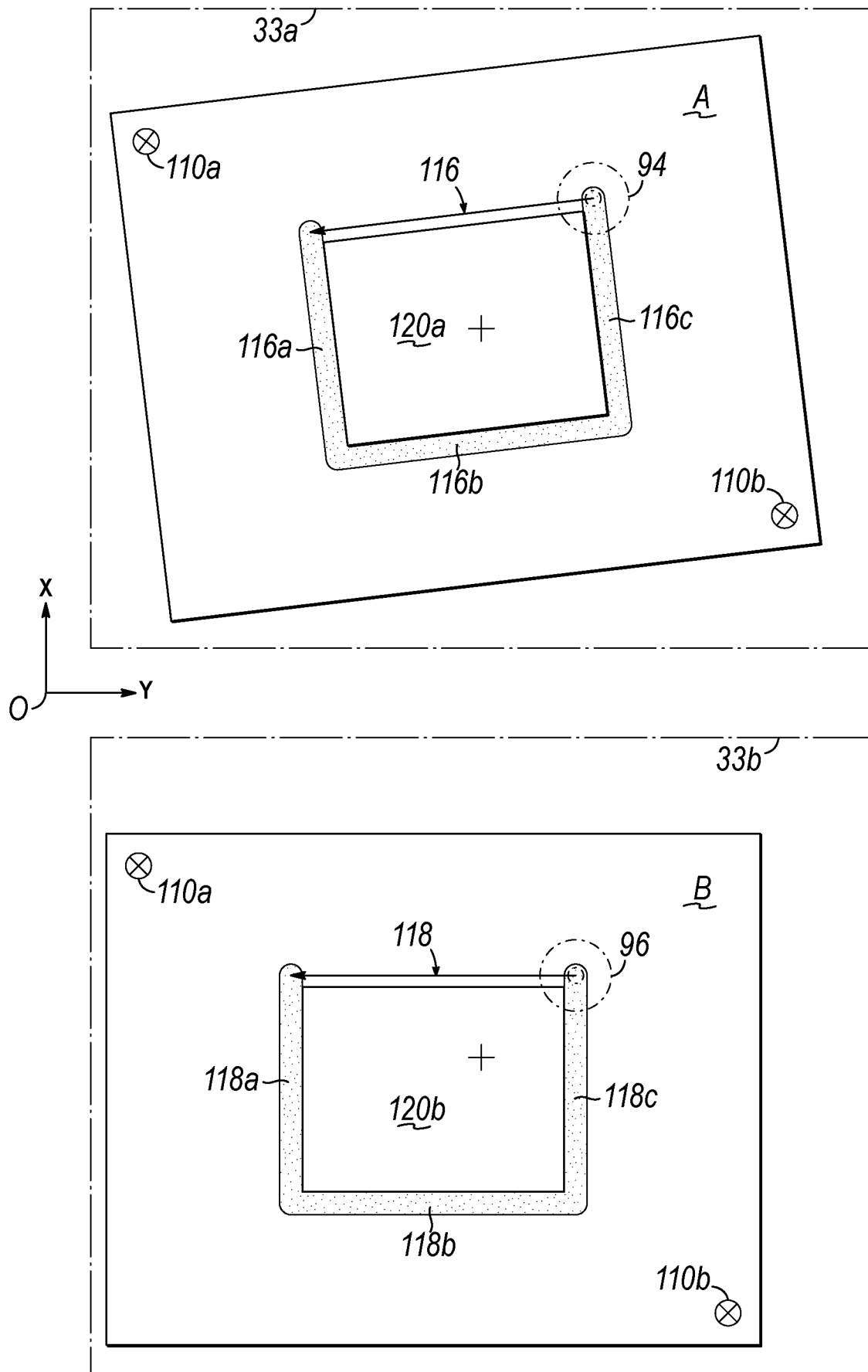


FIG. 10

10/16

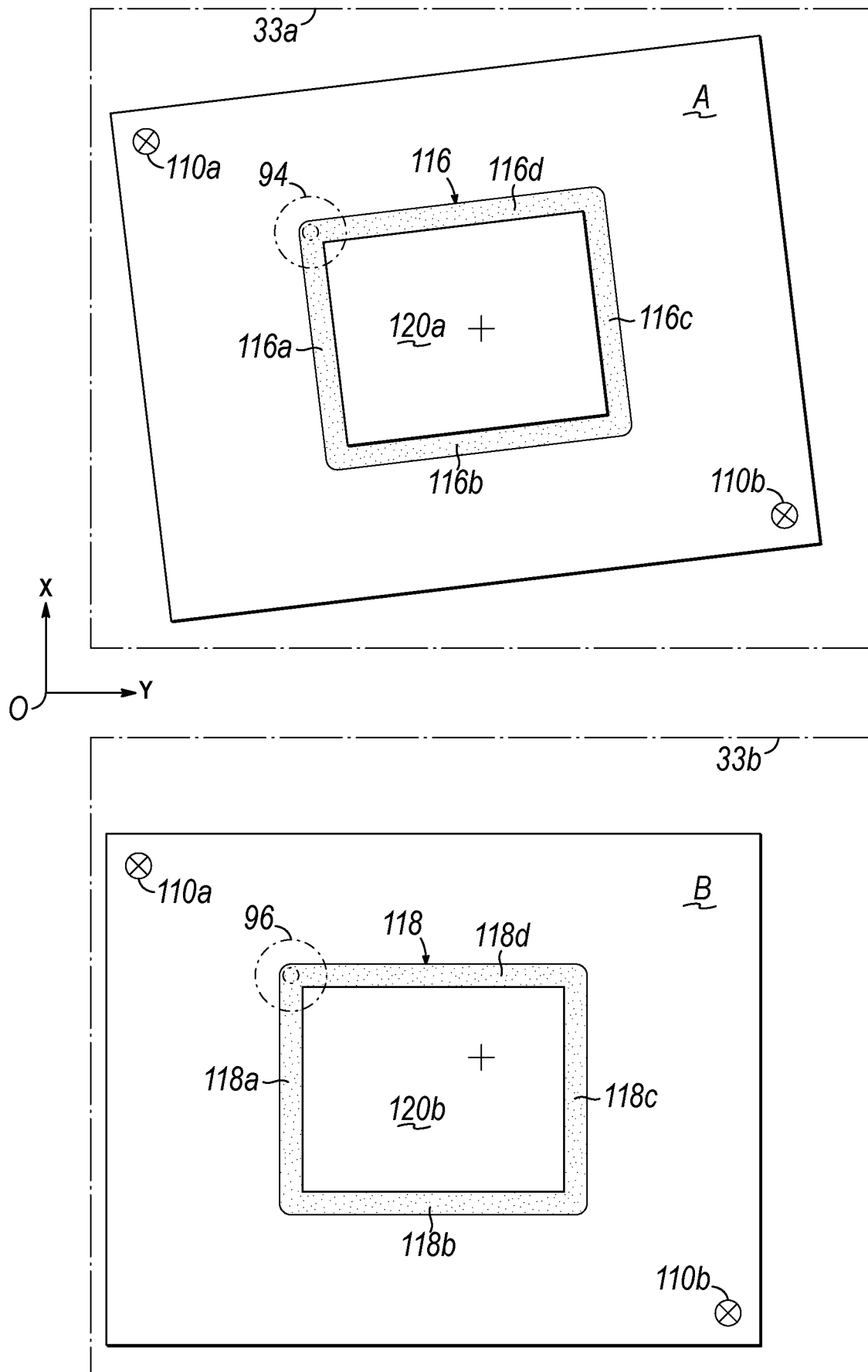
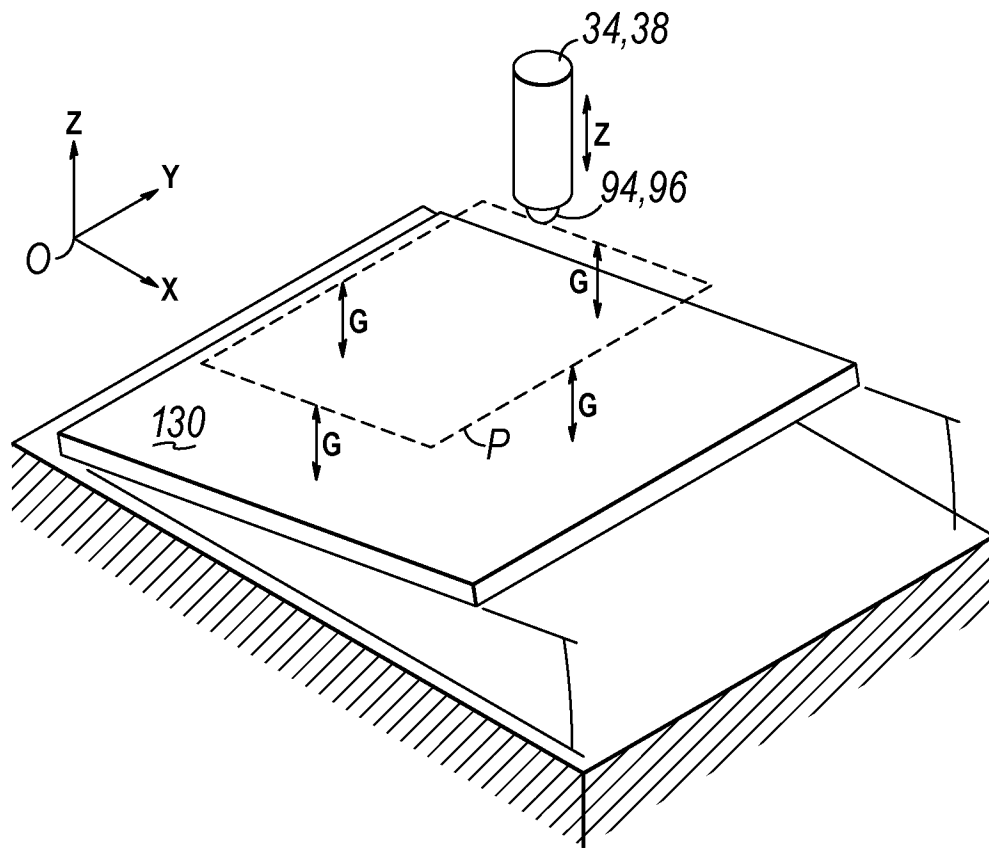
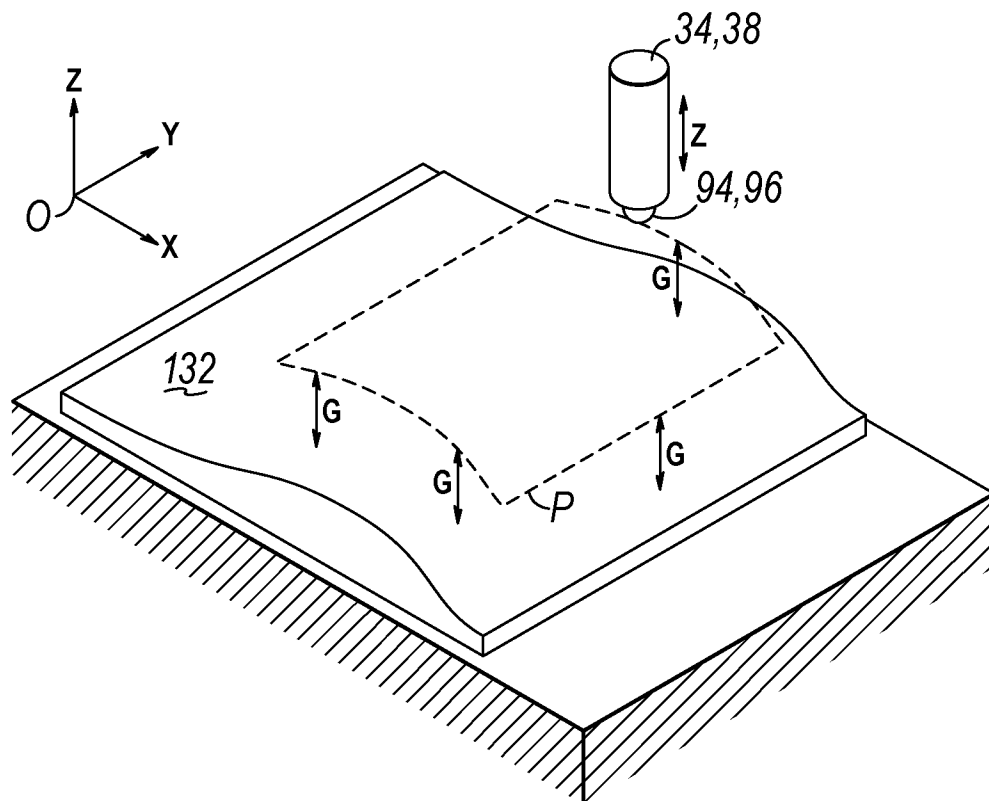


FIG. 11

11/16

**FIG. 12A****FIG. 12B**

12/16

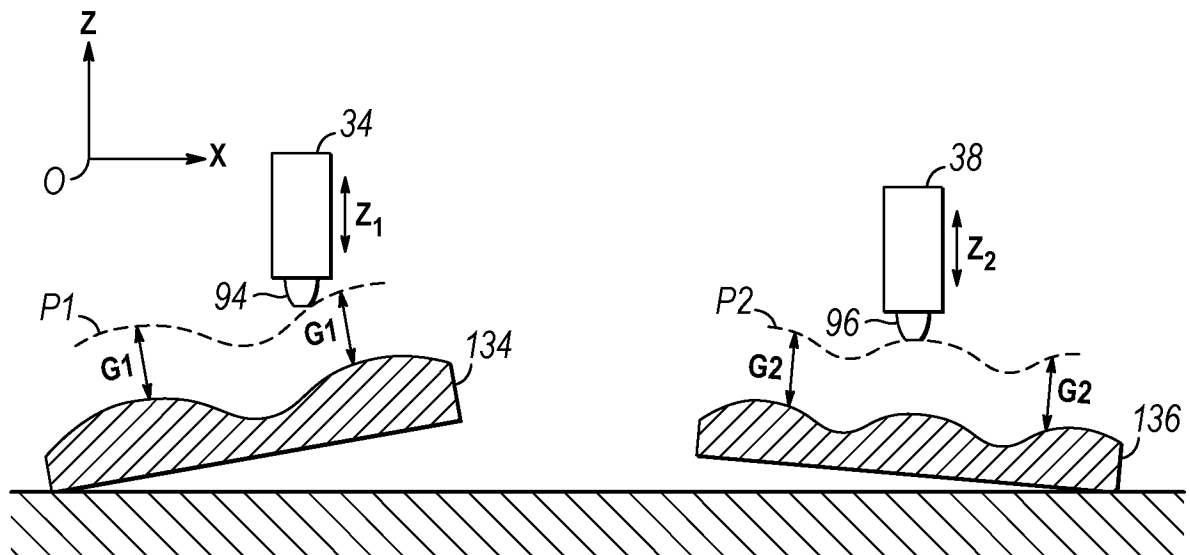


FIG. 13A

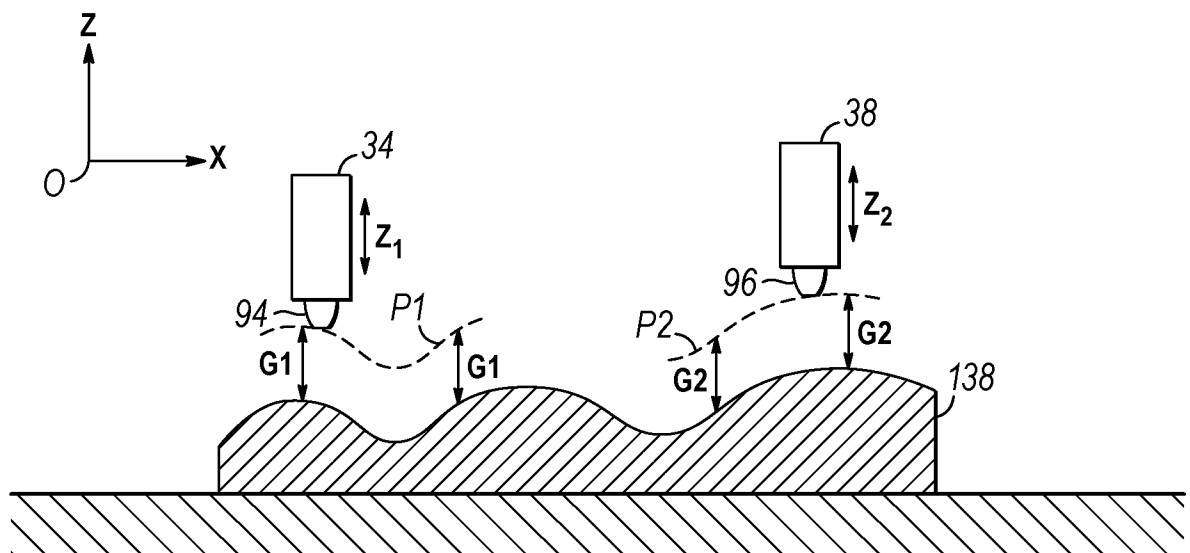


FIG. 13B

13/16

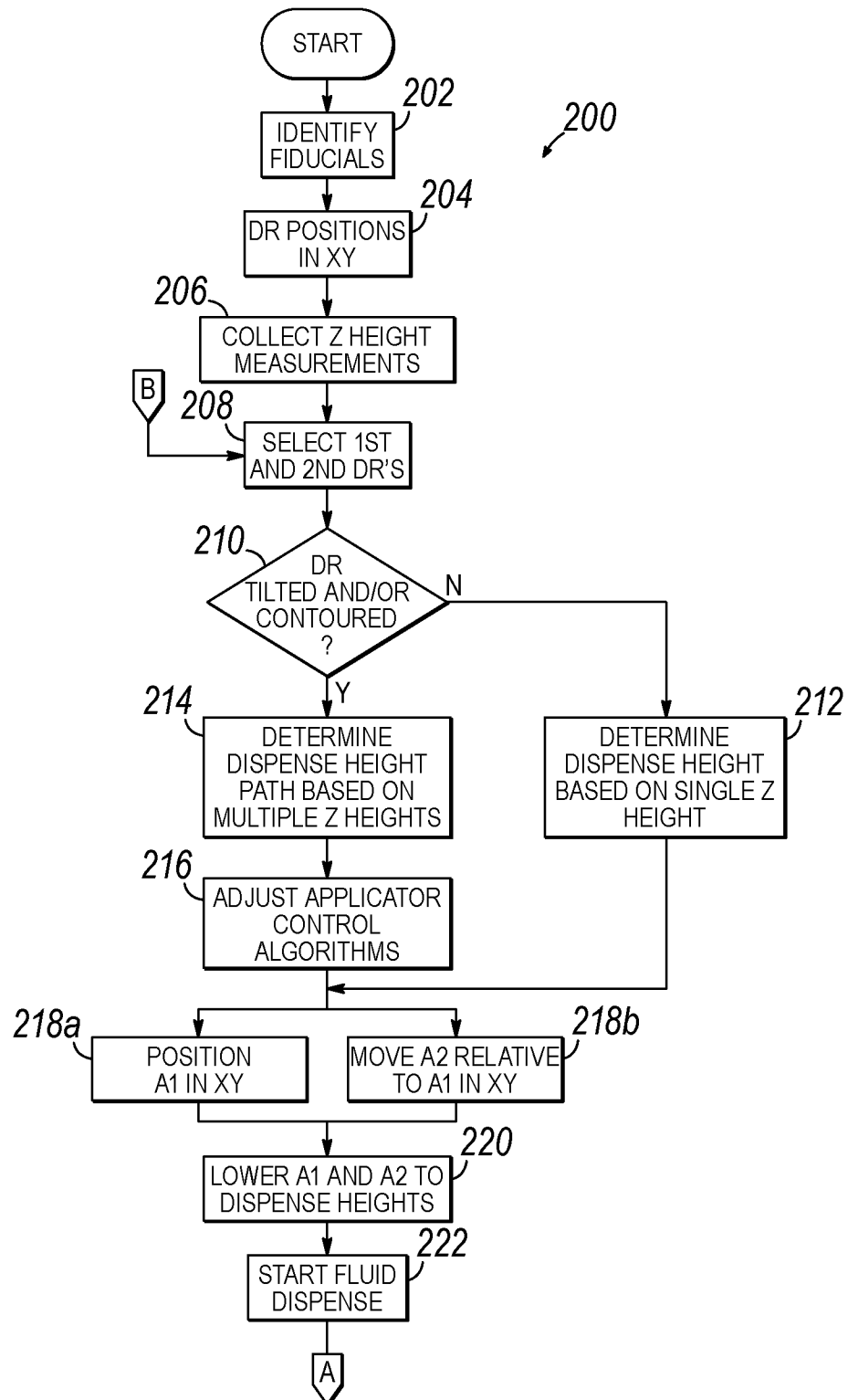


FIG. 14A

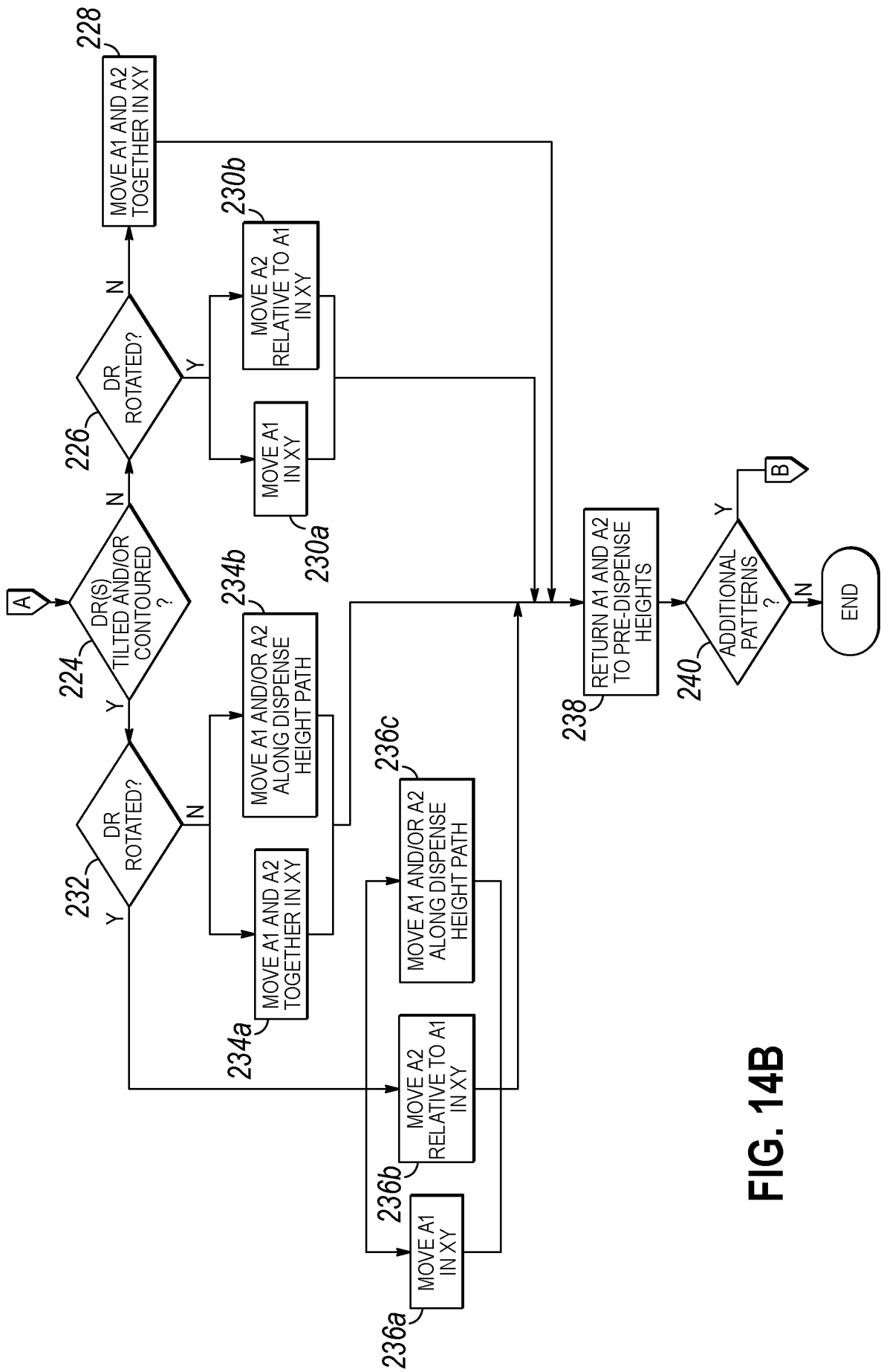


FIG. 14B

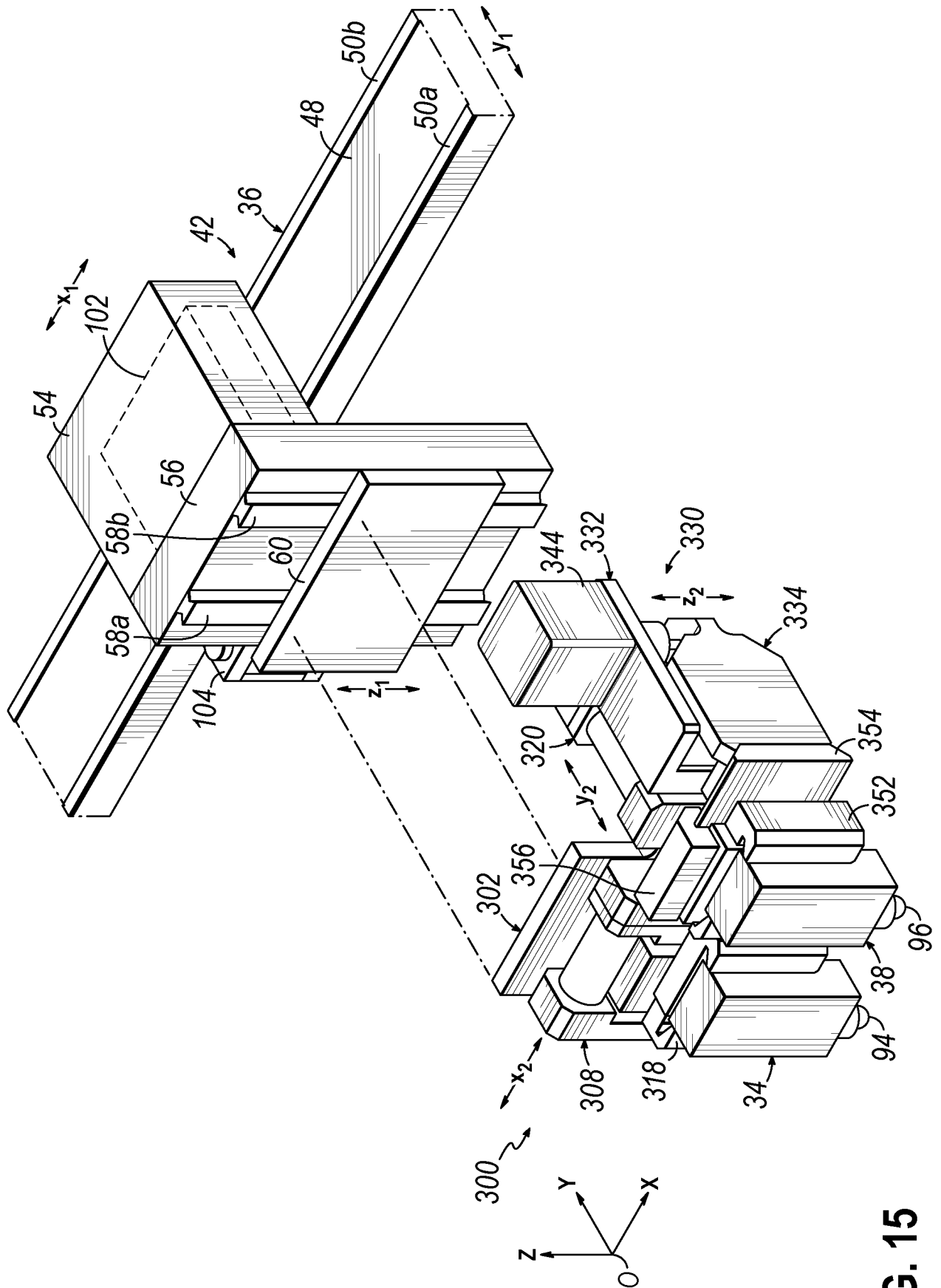


FIG. 15

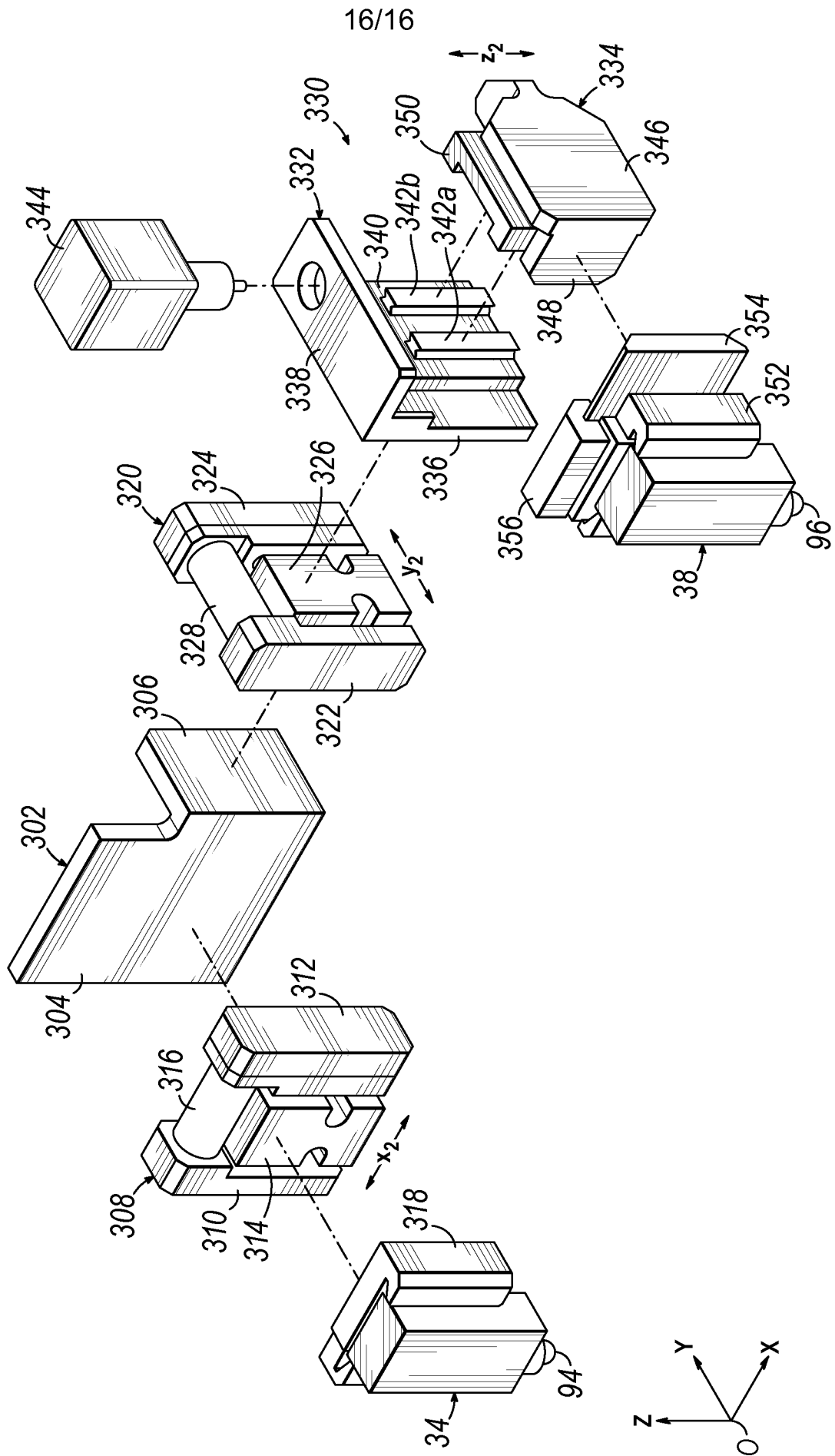


FIG. 16

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2015/039507

A. CLASSIFICATION OF SUBJECT MATTER

INV. H05K13/04 H01L21/67 B05C11/10 B05C5/02
 ADD. B05C13/02

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)

H05K H01L B05C

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 795 390 A (CAVALLARO WILLIAM A [US]) 18 August 1998 (1998-08-18) column 5, line 7 - line 17 column 6, line 13 - column 7, line 7; figures 1,2,5 -----	1-8, 19-23
X	DE 20 2007 019244 U1 (KUKA SYSTEMS GMBH [DE]) 26 August 2011 (2011-08-26) paragraph [0048] figure 1 -----	1-8, 19-23
X	US 6 093 251 A (CARR GREGORY L [US] ET AL) 25 July 2000 (2000-07-25) column 6, line 28 - line 43 page 3 -----	1-8, 19-23



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

13 October 2015

Date of mailing of the international search report

23/12/2015

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
 NL - 2280 HV Rijswijk
 Tel. (+31-70) 340-2040,
 Fax: (+31-70) 340-3016

Authorized officer

Roldán Abalos, Jaime

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/039507

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-8, 19-23

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2015/039507

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5795390 A	18-08-1998	US 5795390 A	18-08-1998
		US 6017392 A	25-01-2000
		US 6224671 B1	01-05-2001
		US 2002008118 A1	24-01-2002

DE 202007019244 U1	26-08-2011	NONE	

US 6093251 A	25-07-2000	CA 2281682 A1	27-08-1998
		EP 0962124 A1	08-12-1999
		ID 23186 A	23-03-2000
		JP 2001512628 A	21-08-2001
		KR 20000071190 A	25-11-2000
		TW 446682 B	21-07-2001
		US 6093251 A	25-07-2000
		US 6391378 B1	21-05-2002
		WO 9837747 A1	27-08-1998

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-8, 19-23

Dispensing system and method for dispensing on tilted or contoured regions.

2. claims: 9-18

Dispensing system for dispensing on locally rotated regions.
