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Declarations under Rule 4.17:

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— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

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(54) **Title**: IMPROVED APPARATUS FOR TEMPORARY WAFER BONDING AND DEBONDING

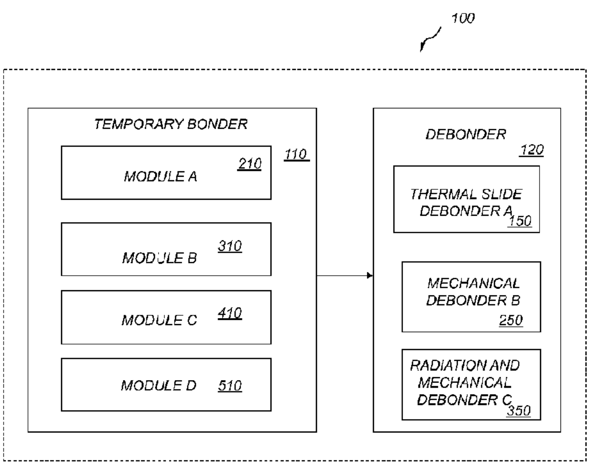

FIG. 1

(57) **Abstract**: An improved apparatus for temporary wafer bonding includes a temporary bonder cluster and a debonder cluster. The temporary bonder cluster includes temporary bonder modules that perform electronic wafer bonding processes including adhesive layer bonding, combination of an adhesive layer with a release layer bonding and a combination of a UV-light curable adhesive layer with a laser absorbing release layer bonding. The debonder cluster includes a thermal slide debonder, a mechanical debonder and a radiation debonder.

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IMPROVED APPARATUS FOR TEMPORARY WAFER BONDING AND DEBONDING

Cross Reference to related Co-Pending Applications

This application claims the benefit of U.S. provisional application Serial No. 61/169,753 filed April 16, 2009 and entitled "IMPROVED APPARATUS FOR TEMPORARY WAFER BONDING", the contents of which are expressly incorporated herein by reference.

Field of the Invention

The present invention relates to an improved apparatus for temporary semiconductor wafer bonding and debonding, and more particularly to an industrial-scale temporary wafer bonding apparatus that comprises various temporary wafer bonding and debonding capabilities.

Background of the Invention

Several semiconductor wafer processes include wafer thinning steps. In some applications the wafers are thinned down to a thickness of less than 100 micrometers for the fabrication of integrated circuit (IC) devices. Thin wafers have the advantages of improved heat removal and better electrical operation of the fabricated IC devices. In one example, GaAs wafers are thinned down to 25 micrometers to fabricate power CMOS devices with improved heat removal. Wafer thinning also contributes to a reduction of the device capacitance and to an increase of its impedance, both of which result in an overall size reduction of the fabricated device. In other applications, wafer thinning is used for 3D-Integration bonding and for fabricating through wafer vias.

Wafer thinning is usually performed via back-grinding and/or chemical mechanical polishing (CMP). CMP involves bringing the wafer surface into contact with a hard and flat rotating horizontal platter in the presence of a liquid slurry. The slurry usually contains abrasive powders, such as diamond or silicon carbide, along with chemical etchants such as ammonia, fluoride, or combinations thereof. The abrasives cause substrate thinning, while the etchants polish the substrate surface at the submicron level. The wafer is maintained in contact with the abrasives until a certain amount of substrate has been removed in order to achieve a targeted thickness.

For wafer thicknesses of over 200 micrometers, the wafer is usually held in place with a fixture that utilizes a vacuum chuck or some other means of mechanical attachment. However, for wafer thicknesses of less than 200 micrometer and especially for wafers of less than 100 micrometers, it becomes increasingly difficult to mechanically hold the wafers and to maintain control of the planarity and integrity of the wafers during thinning. In these cases, it is actually common for wafers to develop microfractures and to break during CMP.

An alternative to mechanical holding of the wafers during thinning involves attaching a first surface of the device wafer (i.e., wafer processed into a device) onto a carrier wafer and thinning down the exposed opposite device wafer surface. The bond between the carrier wafer and the device wafer is temporary and is removed upon completion of the thinning and any other processing steps.

Several temporary bonding techniques have been suggested including using of adhesive compounds that are chemically dissolved after processing or using of adhesive tapes or layers that are thermally or via radiation decomposed after processing. Most of these techniques are device wafer and carrier wafer specific and require customized equipment. It is desirable to provide an apparatus where more than one of the mentioned temporary bonding techniques can be applied to process different types of device wafer/carrier wafer combinations.

Summary of the Invention

In general, in one aspect, the invention features an improved apparatus for temporary bonding and debonding of electronic wafer structures including a cluster of temporary bonder modules and a cluster of debonder modules. The cluster of temporary bonder modules is configured to perform electronic wafer bonding processes comprising at least one of adhesive layer bonding, combination of an adhesive layer with a release layer bonding or a combination of a UV-light curable adhesive layer with a laser absorbing release layer bonding. The cluster of debonder modules is configured to perform debonding processes for debonding electronic wafers bonded via the electronic wafer bonding processes performed by the temporary bonder modules, the debonding processes comprising at least one of thermal-slide debonder, a mechanical debonder or a radiation debonder.

In general, in another aspect, the invention features an improved apparatus for temporary bonding and debonding of electronic wafer structures including a cluster of temporary bonder modules and a cluster of debonder modules. The cluster of temporary bonder modules includes a first bonder module comprising equipment for forming a temporary bond between two wafer surfaces via an adhesive layer and a second bonder module comprising equipment for forming a temporary bond between two wafer surfaces via a combination of an adhesive layer with a release layer. The cluster of debonder modules includes a thermal-slide debonder module and a mechanical debonder. The thermal slide debonder module comprising equipment for debonding two via an adhesive layer temporary bonded wafers. The thermal-slide debonder equipment comprises means for heating the two bonded wafers and means for sliding one wafer relative to the other while heat is applied. The mechanical debonder module comprising equipment for debonding two via a combination of an adhesive layer with a release layer temporary bonded wafers. The mechanical debonder module equipment comprises means for heating the two bonded wafers and means for mechanically pushing one wafer away from the other while heat is applied.

Implementations of this aspect of the invention may include one or more of the following features. The cluster of temporary bonder modules further includes a third bonder module comprising equipment for forming a temporary bond between two wafer surfaces via a combination of a UV-light curable adhesive layer with a laser absorbing release layer. The cluster of debonder modules further includes a radiation debonder module comprising equipment for debonding two via a combination of a UV-light curable adhesive layer with a laser absorbing release layer temporary bonded wafers. The radiation debonder equipment comprises means for applying laser radiation to the two bonded wafers and means for mechanically separating one wafer away from the other. The temporary bonder modules and debonder modules are vertically stacked. The first bonder module equipment comprises means for applying the adhesive layer on a surface of a carrier wafer, means for baking and means for chilling the applied adhesive layer, means for applying a protective layer on a surface of a device wafer, means for baking and means for chilling the applied protective layer, means for orienting and aligning the carrier wafer with the device wafer so that the adhesive layer is opposite to the protective layer, means for bringing the aligned carrier wafer in contact with the device wafer thereby forming a stacked wafer pair, means for applying a force onto the stacked wafer pair and means for heating the stacked wafer pair while force is applied, thereby forming a bonded wafer pair. The second bonder module equipment comprises means for forming a release layer onto a surface of a device wafer and means for applying a first adhesive layer upon the formed release layer, means for applying a second adhesive layer on a surface of a carrier wafer, means for orienting and aligning the carrier wafer with the device wafer so that the second adhesive layer is opposite to the first adhesive layer, means for bringing the aligned carrier wafer in contact with the device wafer thereby forming a stacked wafer pair, means for applying a force onto the stacked wafer pair and means for heating the stacked wafer pair while force is applied, thereby forming a bonded wafer pair. The third bonder module equipment comprises means for applying a UV-light curable adhesive layer onto a surface of a device wafer, means of applying a laser absorbing release layer onto a surface of a carrier wafer, means for orienting and aligning the carrier wafer with the device wafer so that the laser absorbing release layer is opposite to the UV-light curable adhesive layer, means for bringing the aligned carrier wafer in contact with the device wafer thereby forming a stacked wafer pair, means for applying a force onto the stacked wafer pair and means for applying UV-light to the stacked wafer pair while force is applied, thereby forming a bonded wafer pair. Any of the bonder modules includes an upper block assembly, a lower block assembly arranged below and opposite the upper block assembly and a telescoping curtain disposed between the upper and lower block assembly and surrounding and sealing a volume between the upper block assembly and the lower block assembly. The sealed volume defines a temporary bonding chamber containing the bonder module equipment. The bonder module also includes means for evacuating the temporary bonding chamber and means for providing a gas into the temporary bonding chamber. The bonder module further includes two or more Z-guide posts. The upper and lower block assemblies are movably connected to the Z-guide posts. The lower block assembly includes a heater plate having top and bottom surfaces and the heater plate top surface is configured to support and heat a first wafer. The lower block assembly also includes an insulation layer having top and bottom surfaces and the insulation layer top surface in contact with the heater plate bottom surface. The lower block assembly also includes a cooled support flange having top and bottom surfaces and the cooled support flange top surface is in contact with the insulation layer bottom surface. The lower block assembly also includes a transfer pin stage arranged below the cooled support flange and supporting three or more transfer pins passing through the cooled support flange, the insulation layer and the heater plate and configured to raise and lower the first wafer. The lower block assembly also includes a Z-axis block drive comprising a precision Z-drive and a linear encoder feedback for submicron position control and the Z-axis block drive is configured to move the lower block assembly up and down in the Z-direction. The heater plate comprises two independently controlled concentric heating zones configured to heat wafers having a diameter of 200 or 300 millimeters, respectively. The heater plate further comprises two independently controlled concentric vacuum zones configured to hold wafers having a diameter of 200 or 300 millimeters, respectively, onto the heater plate top surface. The upper block assembly includes an upper ceramic chuck configured to hold a second wafer, a static chamber wall against which the telescoping curtain forms a seal with a sealing element, first and second concentric membrane layers having a diameter of 200 and 300 millimeters, respectively, and being clamped between the upper chuck and a top housing wall and three or more adjustable leveling clamp/drive assemblies configured to level and clamp the upper ceramic chuck against the top housing wall. The first and second membrane layer form separate first and second vacuum zones designed to hold wafers having 200 and 300 millimeters, respectively. The upper ceramic chuck comprises a highly flat, thin, semi-compliant ceramic plate. The membrane layers comprise elastomeric materials or metal bellows. The clamp/drive assemblies further comprise a wedge error compensation mechanism that rotates and/or tilts the upper ceramic chuck around a center point corresponding to the center of the held second wafer without translation. The apparatus may further include a mechanical centering device configured to pre-align, load and unload the first and second wafers in any of the bonder modules. The mechanical centering device includes two pre-alignment arms and a stationary jaw. Each pre-alignment arm comprises a mechanical jaw at its first end, the mechanical jaw comprising a tapered surface conforming to the curved edge of the first and second wafers. The stationary jaw has a tapered surface conforming to the curved edge of the first and second wafers.

In general, in another aspect, the invention features a method for temporary bonding two wafer surfaces including the following steps. First, providing a first wafer comprising first and second wafer surfaces opposite to each other. Next, providing a second wafer comprising first and second wafer surfaces opposite to each other. Next, applying an adhesive layer upon the first surface of the second wafer. Next, providing a bonder module comprising an upper block assembly; a lower block assembly arranged below and opposite the upper block assembly; a telescoping curtain disposed between the upper and lower block assembly and surrounding and sealing a volume between the upper block assembly and the lower block assembly, wherein the sealed volume defines a temporary bonding chamber; means for evacuating the temporary bonding chamber means for providing a gas into the temporary bonding chamber. Next, inserting the first wafer into the bonder module and holding the first wafer by the upper block assembly so that its first surface faces down. Next, inserting the second wafer into the bonder module and placing the second wafer upon the lower block assembly so that the adhesive layer is opposite to the first wafer's first surface. Next, centering and aligning the first and second wafers so that the first wafer's first surface is opposite and parallel to the adhesive layer of the second wafer. Next, moving the lower block assembly upward to form a close process gap between the adhesive layer and the first surface of the first wafer. Next, closing the telescoping curtain and thereby forming a temporary bonding chamber surrounding the first and second wafers. Next, evacuating the temporary bonding chamber to an initial deep vacuum while the first wafer is held via mechanical jaws. Upon reaching the initial deep vacuum, providing a gas into the temporary bonding chamber to slightly raise the temporary bonding chamber pressure above the initial deep vacuum, thereby generating a differential pressure that holds the first wafer in contact with the upper block assembly. Next, moving the lower block assembly upward to bring the adhesive layer in contact with the first surface of the first wafer. Next, applying a force to the first and second wafers via the upper block assembly while heating the first and second wafers to a process temperature above the melting point of the adhesive layer thereby forming a temporary bonded wafer pair. Next, cooling the bonded wafer pair and unloading it from the bonder module.

Implementations of this aspect of the invention may include one or more of the following features. The upper block assembly comprises a semi-compliant chuck and the force is applied perpendicular to the bond interface of the first and second wafers via the semi-compliant chuck. The upper block comprises a non-compliant chuck and the method further comprises controlling the final thickness of the adhesive layer in the bonded wafer pair via the upward motion of the lower block assembly.

In general, in one aspect, the invention features a debonder apparatus for debonding two via an adhesive layer temporary bonded wafers including a top chuck assembly, a bottom chuck assembly, a static gantry supporting the top chuck assembly, an X-axis carriage drive supporting the bottom chuck assembly, and an X-axis drive control. The top chuck assembly includes a heater and a wafer holder. The X-axis drive control drives horizontally the bottom chuck assembly from a loading zone to a process zone under the top chuck assembly and from the process zone back to the loading zone. A wafer pair comprising a carrier wafer bonded to a device wafer via an adhesive layer is placed upon the bottom chuck assembly at the loading zone oriented so that the unbonded surface of the device wafer is in contact with the bottom assembly and is carried by the X-axis carriage drive to the process zone under the top chuck assembly and the unbonded surface of the carrier wafer is placed in contact with the top chuck assembly. The X-axis drive control initiates horizontal motion of the X-axis carriage drive along the X-axis while heat is applied to the carrier wafer via the heater and while the carrier wafer is held by the top chuck assembly via the wafer holder and thereby causes the device wafer to separate and slide away from the carrier wafer.

Implementations of this aspect of the invention may include one or more of the following features. The debonder further includes a lift pin assembly designed to raise and lower wafers placed on the bottom chuck assembly. The debonder further includes a base plate supporting the X-axis carriage drive and the static gantry. The base plate comprises a honeycomb structure and vibration isolation supports or a granite plate. The bottom chuck assembly includes a bottom chuck comprising a low thermal mass ceramic material and is designed to slide horizontally along the X-axis upon the X-axis carriage drive and to twist around the Z-axis. The X-axis carriage drive comprises an air bearing carriage drive. The debonder further includes two parallel lateral carriage guidance tracks guiding the X-axis carriage drive in its horizontal motion along the X-axis. The top chuck assembly further includes a top support chuck bolted to the static gantry, a heater support plate in contact with the bottom surface of the top support chuck, the heater being in contact with the bottom surface of the heater support plate, a top wafer plate in contact with the heater, a Z-axis drive for moving the top wafer plate in the Z-direction and placing the top wafer plate in contact with the unbonded surface of the carrier wafer and a plate leveling system for leveling the top wafer plate and for providing wedge error compensation of the top wafer plate. The wafer holder may be vacuum pulling the carrier wafer. The plate leveling system comprises three guide shafts connecting the heater to the top support chuck and three pneumatically actuated split clamps. The heater comprises two independently controlled concentric heating zones configured to heat wafers having a diameter of 200 or 300 millimeters, respectively.

In general, in another aspect, the invention features a method for debonding two via an adhesive layer temporary bonded wafers, including the following steps. First, providing a bonder comprising a top chuck assembly, a bottom chuck assembly, a static gantry supporting the top chuck assembly, an X-axis carriage drive supporting the bottom chuck assembly and an X-axis drive control configured to drive horizontally the X-axis carriage drive and the bottom chuck assembly from a loading zone to a process zone under the top chuck assembly and from the process zone back to the loading zone. Next, loading a wafer pair comprising a carrier wafer bonded to a device wafer via an adhesive layer upon the bottom chuck assembly at the loading zone oriented so that the unbonded surface of the device wafer is in contact with the bottom assembly. Next, driving the X-axis carriage drive and the bottom chuck assembly to the process zone under the top chuck assembly. Next, placing the unbonded surface of the carrier wafer in contact with the top chuck assembly and holding the carrier wafer by the top chuck assembly. Next, heating the carrier wafer with a heater comprised in the top chuck assembly. Finally, initiating horizontal motion of the X-axis carriage drive along the X-axis by the X-axis drive control while heat is applied to the carrier wafer and while the carrier wafer is held by the top chuck assembly and thereby causing the device wafer to separate and slide away from the carrier wafer.

In general, in one aspect, the invention features a debonder apparatus for debonding two via an adhesive layer combined with a release layer temporary bonded wafers including a chuck assembly, a flex plate assembly and a contact roller. The chuck assembly includes a chuck and a first wafer holder configured to hold wafers in contact with the top surface of the chuck. The flex plate assembly includes a flex plate and a second wafer holder configured to hold wafers in contact with a first surface of the flex plate. The flex plate comprises a first edge connected to a hinge and a second edge diametrically opposite to the first edge, and the flex plate's first edge is arranged adjacent to a first edge of the chuck and the flex plate is configured to swing around the hinge and to be placed above the top surface of the chuck. The contact roller is arranged adjacent to a second edge of the chuck, the second edge of the chuck being diametrically opposite to its first edge. A debond drive motor is configured to move the contact roller vertical to the plane of the chuck top surface. In operation, a wafer pair, comprising a carrier wafer stacked upon and being bonded to a device wafer via an adhesive layer and a release layer, is placed upon the chuck so that the ubonded surface of the device wafer is in contact with the chuck top surface. Next, the flex plate swings around the hinge and is placed above the bottom chuck so that its first surface is in contact with the unbonded surface of the carrier wafer. Next, the contact roller is driven upward until it contacts and pushes the second edge of the flex plate up while the carrier wafer is held by the flex plate and the device wafer is held by the chuck via the second and first wafer holders, respectively. The contact roller push flexes the second edge of the flex plate and causes delamination of the wafer pair along the release layer.

Implementations of this aspect of the invention may include one or more of the following features. The debonder may further include a hinge motor that drives the hinge. The first and second holders comprise vacuum pulling through the chuck and the flex plate, respectively. The wafer pair further includes a tape frame and the device wafer is held by the chuck by holding the tape frame via the vacuum pulled through the chuck. The debonder further includes a support plate supporting the chuck assembly, the flex plate assembly and the hinge. The debonder further includes a base plate supporting the support plate, the contact roller, the hinge motor and the debond drive motor. The flex plate assembly further includes a lift pin assembly designed to raise and lower wafers placed on the first surface of the flex plate. The flex plate further includes two independently controlled concentric vacuum zones configured to hold wafers having a diameter of 200 or 300 millimeters, respectively. The vacuum zones are sealed via one of an O-ring or suction cups. The chuck comprises a vacuum chuck made of porous ceramic materials. The debonder further includes an anti-backlash gear drive configured to prevent accidental back swing of the flex pate.

In general, in another aspect, the invention features a method for debonding two via an adhesive layer combined with a release layer temporary bonded wafers. The method includes the following steps. First, providing a debond apparatus comprising a chuck assembly, a flex plate assembly and a contact roller. The chuck assembly comprises a chuck and a first wafer holder configured to hold wafers in contact with the top surface of the chuck. The flex plate assembly comprises a flex plate and a second wafer holder configured to hold wafers in contact with a first surface of the flex plate. The flex plate comprises a first edge connected to a hinge and a second edge diametrically opposite to the first edge, and the flex plate's first edge is arranged adjacent to a first edge of the chuck and the flex plate is configured to swing around the hinge and to be placed above the top surface of the chuck. The contact roller is arranged adjacent to a second edge of the chuck, the second edge of the chuck being diametrically opposite to its first edge. Next, providing a wafer pair comprising a carrier wafer stacked upon and being bonded to a device wafer via an adhesive layer and a release layer. Next, placing the wafer pair upon the chuck so that the ubonded surface of the device wafer is in contact with the chuck top surface. Next, swinging the flex plate around the hinge and placing it above the bottom chuck so that its first surface is in contact with the unbonded surface of the carrier wafer. Next, driving the contact roller upward until it contacts and pushes the second edge of the flex plate up while the carrier wafer is held by the flex plate and the device wafer is held by the chuck via the second and first wafer holders, respectively. Finally, the contact roller push flexes the second edge of the flex plate and causes delamination of the wafer pair along the release layer.

In general, in one aspect, the invention features a device for centering circular wafers including a support chuck for supporting a circular wafer to be centered upon its top surface, first and second rotationally movable alignment arms and a third linear moving alignment arm. The first and second rotationally movable alignment arms are rotatable around an axis perpendicular to the top surface of the support chuck and comprise first and second mechanical jaws, respectively. The first and second mechanical jaws comprise a tapered curved edge surface conforming to the curved edge of the circular wafer. The third linear moving alignment arm comprises a tapered curved inner surface conforming to the curved edge of the circular wafer. The first, second and third alignment arms are arranged around the support chuck at an angle of 120 degrees from each other. In operation, a circular wafer placed on the support chuck is centered and aligned by rotating the first and second alignment arms toward the center of the support chuck so that the tapered curved edge surfaces of the first and second mechanical jaws contact the outer perimeter of the circular wafer at first and second perimeter areas, respectively, and by linearly moving the third alignment arm toward the center of the support chuck so that its tapered curved inner surface contacts the outer perimeter of the circular wafer at third perimeter area. The first, second and third perimeter areas are separated by an angle of 120 degrees from each other. The mechanical jaws may have a first tapered curved edge surface conforming to the curved edge of a circular wafer having a diameter of 200 millimeters and a second tapered curved edge surface conforming to the curved edge of a circular wafer having a diameter of 300 millimeters.

In general, in another aspect, the invention features a device for centering circular wafers including a support chuck for supporting a circular wafer to be centered upon its top surface and first, second and third rotationally movable alignment arms. The first, second and third rotationally movable alignment arms are rotatable around an axis perpendicular to the top surface of the support chuck and comprise first, second and third mechanical jaws, respectively, the first mechanical jaws comprising a tapered curved edge surface conforming to the curved edge of the circular wafer. The first, second and third alignment arms are arranged around the support chuck at an angle of 120 degrees from each other. A circular wafer placed on the support chuck is centered and aligned by rotating the first, second and third alignment arms toward the center of the support chuck so that the tapered curved edge surfaces of the first, second and third mechanical jaws contact the outer perimeter of the circular wafer at first, second and third perimeter areas, respectively. The first, second and third perimeter areas are separated by an angle of 120 degrees from each other. The mechanical jaws may have a first tapered curved edge surface conforming to the curved edge of a circular wafer having a diameter of 200 millimeters and a second tapered curved edge surface conforming to the curved edge of a circular wafer having a diameter of 300 millimeters.

In general, in another aspect, the invention features a device for centering circular wafers including a support chuck for supporting a circular wafer to be centered upon its top surface, left, right and middle centering linkage rods and a cam plate synchronizing the rectilinear motion of the left, right and middle centering linkage rods. The left centering linkage rod includes a first rotating arm at a first end, and rectilinear motion of the left centering linkage rod translates into rotational motion of the first rotating arm. The first rotating arm is rotatable around an axis perpendicular to the top surface of the support chuck and comprises a curved edge surface configured to roll against the curved edge of the circular wafer. The right centering linkage rod comprises a second rotating arm at a first end, and rectilinear motion of the right centering linkage rod translates into rotational motion of the second rotating arm. The second rotating arm is rotatable around an axis perpendicular to the top surface of the support chuck and comprises a curved edge surface configured to roll against the curved edge of the circular wafer. The middle centering linkage rod includes a third alignment arm at a first end. The third alignment arm is placed in contact with the curved edge of the circular wafer and linear motion of the middle centering linkage rod in the Y-direction pushes the third alignment arm and the circular wafer toward or away from the center of the support chuck. The cam plate includes first and second linear cam profiles. The first cam profile provides rectilinear motion for the middle centering linkage rod and the second linear cam profile provides rectilinear motion for the left and right centering linkage rods.

Implementations of this aspect of the invention may include one or more of the following features. The first and second cam linear profiles comprise surfaces arranged at an angle relative to each other and relative to the Y-direction. The device further includes a connection rod attached to second ends of the left and right centering linkage rods and the connection rod is configured to roll along the second linear cam profile of the cam plate. The middle centering linkage rod comprises a roller at a second end and the roller is configured to roll along the first linear cam profile of the cam plate. The device further includes a motor and a linear slide and the cam plate is fixed to the linear slide and the motor provides rectilinear motion to the linear slide and thereby to the cam plate. The device also includes a sensor indicating that the first, second and third alignment arms are in contact with the curved edge of the circular wafer. The sensor may be a linear variable differential transformer (LVDT) or an electric sensor.

In general, in another aspect, the invention features a device for centering circular wafers including a support chuck for supporting a circular wafer to be centered upon its top surface, left, right and middle centering linkage rods and first and second cam plates synchronizing the rectilinear motion of the left, right and middle centering linkage rods. The left centering linkage rod comprises a first rotating arm at a first end, and rectilinear motion of the left centering linkage rod translates into rotational motion of the first rotating arm. The first rotating arm is rotatable around an axis perpendicular to the top surface of the support chuck and comprises a curved edge surface configured to roll against the curved edge of the circular wafer. The right centering linkage rod comprises a second rotating arm at a first end, and rectilinear motion of the right centering linkage rod translates into wise rotational motion of the second rotating arm. The second rotating arm is rotatable around an axis perpendicular to the top surface of the support chuck and comprises a curved edge surface configured to roll against the curved edge of the circular wafer. The middle centering linkage rod comprises a third alignment arm at a first end, and the third alignment arm is placed in contact with the curved edge of the circular wafer. Linear motion of the middle centering linkage rod in the Y-direction pushes the third alignment arm and the circular wafer toward or away from the center of the support chuck. The first and second cam plates comprise first and second linear cam profiles, respectively, and the first cam profile provides rectilinear motion for the left centering linkage rod and the second cam profile provides rectilinear motion for the right linkage rod. A linear slide is connected to a second end of the middle centering linkage rod and provides linear motion in the Y-direction to the middle centering linkage rod. The first and second cam plates are connected to the linear slide via first and second connection rods, respectively, and linear motion of the linear slide in the Y-direction is translated into linear motion of the first and second cam plates in the X-direction.

The details of one or more embodiments of the invention are set forth in the accompanying drawings and description below. Other features, objects and advantages of the invention will be apparent from the following description of the preferred embodiments, the drawings and from the claims.

Brief Description of the Drawings

Referring to the figures, wherein like numerals represent like parts throughout the several views:

FIG. 1 is an overview schematic diagram of the improved temporary wafer bonder and debonder system according to this invention;

FIG. 1A is a schematic diagram of temporary wafer bonding process A and debonding process A performed in bonder module A and debonder A of FIG. 1, respectively;

FIG. 1B depicts a schematic cross-sectional view of the bonder module A of FIG. 1 and a list of the process steps for performing the temporary wafer bonding process A of FIG. 1A;

FIG. 2A is a schematic diagram of temporary wafer bonding process B and debonding process B performed in bonder module B and debonder B of FIG. 1, respectively;

FIG. 2B depicts a schematic cross-sectional view of the bonder module B of FIG. 1 and a list of the process steps for performing the temporary wafer bonding process B of FIG. 2A;

FIG. 3A is a schematic diagram of temporary wafer bonding process C and debonding process C performed in bonder module C and debonder C of FIG. 1, respectively;

FIG. 3B depicts a schematic cross-sectional view of the bonder module C of FIG. 1, and a list of the process steps for performing the temporary wafer bonding process C of FIG. 3A;

FIG. 4 depicts a view of a fixture chuck;

FIG. 5 depicts the temporary wafer bonder cluster of FIG. 1;

FIG. 6 depicts a closer view of the upper structure of the temporary wafer bonder cluster of FIG. 5;

FIG. 7 depicts a cross-sectional view of the upper structure of the temporary wafer bonder cluster of FIG. 5;

FIG. 8 depicts the hot plate module of the temporary wafer bonder cluster of FIG. 7;

FIG. 9 depicts a temporary bond module of the wafer bonder cluster of FIG. 7;

FIG. 10 depicts a schematic cross-sectional diagram of the temporary bonder module of FIG. 9;

FIG. 11 depicts a cross-sectional view of the temporary wafer bonder module of FIG. 9 perpendicular to the load direction;

FIG. 12 depicts a cross-sectional view of the temporary wafer bonder module of FIG. 9 in line with the load direction;

FIG. 13 depicts the top chuck leveling adjustment in the temporary wafer bonder module of FIG. 9;

FIG. 14 depicts a cross-sectional view of the top chuck of the temporary wafer bonder module of FIG. 9;

FIG. 15 depicts a detailed cross-sectional view of the temporary wafer bonder module of FIG. 9;

FIG. 16 depicts a wafer centering device with the pre-alignment arms in the open position;

FIG. 17 depicts wafer centering device of FIG. 16 with the pre-alignment arms in the closed position;

FIG. 18A depicts the pre-alignment of a 300 mm wafer;

FIG. 18B depicts the pre-alignment of a 200 mm wafer;

FIG. 19A depicts another wafer centering device for the pre-alignment of a 300 mm wafer;

FIG. 19B depicts the wafer centering device of FIG. 19A for the pre-alignment of a 200 mm wafer;

FIG. 19C depicts another wafer centering device for the pre-alignment of a wafer with the rotating arms in the open position;

FIG. 19D depicts the wafer centering device of FIG. 19C with the rotating arms in the closed position;

FIG. 20A, FIG. 20B and FIG. 20C depict the loading of the non-adhesive substrate and its transfer to the upper chuck;

FIG. 21A, FIG. 21B and FIG. 21C depict the loading of the adhesive substrate and its transfer to the lower chuck;

FIG. 22A and FIG. 22B depict bringing the adhesive substrate in contact with the non-adhesive substrate and the formation of a temporary bond between the two substrates;

FIG. 23 depicts an overview diagram of the thermal slide debonder A of FIG. 1;

FIG. 24 depicts a cross-sectional view of the top chuck assembly of the debonder A of FIG. 23;

FIG. 25 depicts a cross-sectional side view of the debonder A of FIG. 23;

FIG. 26A, FIG. 26B and FIG. 26C depict the thermal slide debonder A operational steps;

FIG. 27 depicts an overview diagram of the mechanical debonder B of FIG. 1;

FIG. 28 depicts a cross-sectional side view of the debonder B of FIG. 27; and

FIG. 29 depicts the debonder B operational steps.

Detailed Description of the Invention

Referring to FIG. 1, an improved apparatus for temporary wafer bonding and debonding 100 includes a temporary bonder cluster 110 and a debonder cluster 120. The temporary bonder cluster 110 includes temporary bonder module A, module B, module C, and module D, 210, 310, 410 and 510 respectively. Debonder cluster 120 includes a thermal slide debonder A 150, a mechanical debonder B 250 and a radiation /mechanical debonder C 350. Bonder cluster 110 facilitates the temporary bonding processes A, B, C, and D, 60a, 70a, 80a and 90a, shown in FIG. 1A, FIG. 2A, FIG. 3A, and FIG. 4, respectively, among others. Debonder cluster 120 facilitates the debonding processes A, B and C, 60b, 70b, and 80b, shown in FIG. 1A, FIG. 2A and FIG. 3A, respectively.

Referring to FIG. 1A, temporary bond process A 60a includes the following steps. First, device wafer 20 is coated with a protective coating 21 (62), the coating is then baked and chilled (63) and then the wafer is flipped (64). A carrier wafer 30 is coated with an adhesive layer 31 (65) and then the coating is baked and chilled (66). In other embodiments, a dry adhesive film is laminated onto the carrier wafer, instead of coating an adhesive layer. Next, the flipped device wafer 20 is aligned with the carrier wafer 30 so that the surface of the device wafer with the protective coating 20a is opposite to the surface of the carrier wafer with the adhesive layer 30a (67) and then the two wafers are bonded (68) in temporary bonder module A, shown in FIG. 1B. The bond is a temporary bond between the protective layer 21 and the adhesive layer 31. In other embodiments, no protective coating is applied onto the device wafer surface and the device wafer surface 20a is directly bonded with the adhesive layer 31. Examples of device wafers include GaAs wafers, silicon wafers, or any other semiconductor wafer that needs to be thinned down to less than 100 micrometers. These thin wafers are used in military and telecommunication applications for the fabrication of power amplifiers or other power devices where good heat removal and small power factor are desirable. The carrier wafer is usually made of a non-contaminating material that is thermally matched with the device wafer, i.e., has the same coefficient of thermal expansion (CTE). Examples of carrier wafer materials include silicon, glass, sapphire, quartz or other semiconductor materials. The diameter of the carrier wafer is usually the same as or slightly larger than the diameter of the device wafer, in order to support the device wafer edge and prevent cracking or chipping of the device wafer edge. In one example, the carrier wafer thickness is about 1000 micrometers and the total thickness variation (TTV) is 2-3 micrometers. Carrier wafers are recycled and reused after they are debonded from the device wafer. In one example, adhesive layer 31 is an organic adhesive WaferBOND™ HT-10.10, manufactured by Brewer Science, Missouri, USA. Adhesive 31 is applied via a spin-on process and has a thickness in the range of 9 to 25 micrometers. The spin speed is in the rage of 1000 to 2500 rpm and the spin time is between 3-60 second. After the spin-on application, the adhesive layer is baked for 2 min at a temperature between 100 °C to 150 °C and then cured for 1-3 minutes at a temperature between 160 °C to 220 °C. WaferBOND™ HT-10.10 layer is optically transparent and is stable up to 220 °C. After the thinning of the exposed device wafer surface 20b the carrier wafer 30 is debonded via the debond process A 60b, shown in FIG. 1A. Debond process A 60b, includes the following steps. First heating the wafer stack 10 until the adhesive layer 31 softens and the carrier wafer 30 slides off from the thinned wafer (69). The WaferBOND™ HT-10.10 debonding time is less than 5 minutes. The thinned wafer 20 is then cleaned, any adhesive residue is stripped away (52) and the thinned wafer is placed in a dicing frame 25 (53) In some embodiments, a small rotational motion (twisting) of the carrier wafer takes place prior to the sliding translational motion.

The temporary bonding (68) of the carrier wafer 30 to the device wafer 20 takes place in temporary bonder module A, 210. Referring to FIG. 1B, the device wafer 20 is placed in the fixture chuck 202 and the fixture chuck is loaded in the chamber 210. The carrier wafer 30 is placed with the adhesive layer facing up directly on the bottom chuck 210a and the two wafers 20, 30 are stacked and aligned. The top chuck 210b is lowered down onto the stacked wafers and a low force is applied. The chamber is evacuated and the temperature is raised to 200 °C for the formation of the bond between the protective coating layer 21 and the adhesive layer 31. Next, the chamber is cooled and the fixture is unloaded.

The debond process A 60b is a thermal slide debond process and includes the following steps, shown in FIG. 1A. The bonded wafer stack 10 is heated causing the adhesive layer 31 to become soft. The carrier wafer is then twisted around axis169 and then slid off the wafer stack under controlled applied force and velocity (69). The separated device wafer 20 is then cleaned (52) and mounted onto a dicing frame 25 (53).

Referring to FIG. 2A, temporary bond process B 70a includes the following steps. First, a release layer 22 is formed onto a surface 20a of the device wafer 20 (72). The release layer is formed by first spin-coating a precursor compound onto the wafer device surface 20a and then performing Plasma Enhanced Chemical Vapor deposition (PECVD) in a commercially available PECVD chamber. In one example, the precursor for the release layer is SemicoSil™, a silicon rubber manufactured by Wacker, Germany. The coated device wafer is then spin coated with an adhesive (73) and then flipped (74). Next, a soft layer 32 is spin coated on a surface 30a of the carrier wafer 30 (76). In one example, soft layer 32 is a hot temperature cross-linking (HTC) silicone elastomer. Next, the flipped device wafer 20 is aligned with the carrier wafer 30 so that the surface 20a of the device wafer with the release layer 22 is opposite to the surface 30a of the carrier wafer with the soft layer 32 (77) and then the two wafers are bonded (78) in the temporary bonder module B, shown in FIG. 2B. The temporary bond is formed under vacuum of 0.1 mbar, curing temperature between 150 °C to 200 °C and low applied bond force.

Referring to FIG. 2B, the device wafer 20 is placed in the fixture chuck 202 (shown in FIG. 4) with the adhesive layer facing up. Next, spacers 203 are placed on top of the device wafer 20 and then the carrier wafer 30 is placed on top of the spacers and the assembled fixture chuck 202 is transferred to the bonder module B 310. The chamber is evacuated, the spacers 203 are removed and the carrier wafer 30 is dropped onto the device wafer 20. In some embodiments, the carrier wafer 30 is dropped onto the device wafer 20 by purging nitrogen or other inert gas through vacuum grooves formed in the upper chuck 222. In other embodiments the upper chuck 222 is an electrostatic chuck (ESC) and the carrier wafer 30 is dropped onto the device wafer 20 by reversing the polarity of the ESC. Next, a low force is applied by purging the chamber with a low pressure gas and the temperature is raised to 200 °C for the formation of the bond. Next, the chamber is cooled and the fixture is unloaded. In other embodiments, the Z-axis 239 moves up and the stacked wafers 20, 30 are brought into contact with the upper chuck 222. The upper chuck 222 may be semi-compliant or non-compliant, as will be described later.

The debond process B 70b is a mechanical lift debond process and includes the following steps, shown in FIG. 2A. The bonded wafer stack 10 is mounted onto a dicing frame 25 (54) and the carrier wafer 30 is mechanically lifted away from the device wafer 20 (55). The thinned device wafer 20 remains supported by the dicing frame 25.

Referring to FIG. 3A, temporary bond process C, 80a includes the following steps. First, a surface of the device wafer 20 is coated with an adhesive layer 23 (82). In one example, adhesive layer 23 is a UV curable adhesive LC3200™, manufactured by 3M Company, MN, USA. The adhesive coated device wafer is then flipped (84). Next, a light absorbing release layer 33 is spin coated on a surface 30a of the carrier wafer 30 (86). In one example, light absorbing release layer 33 is a LC4000, manufactured by 3M Company, MN, USA. Next, the flipped device wafer 20 is aligned with the carrier wafer 30 so that the surface 20a of the device wafer with the adhesive layer 23 is opposite to the surface 30a of the carrier wafer 30 with the light absorbing release layer. The two surfaces 20a and 30a are brought into contact and the adhesive layer is cured with UV light (87). The two wafers are bonded (88) in temporary bonder module C 410, shown in FIG. 3B. The bond is a temporary bond between the light absorbing release layer 33 and the adhesive layer 23 and is formed under vacuum of 0.1 mbar and low applied bond force. The temporary bonding (88) of the carrier wafer to the device wafer occurs in temporary module C, shown in FIG. 3B.

Referring to FIG. 3B, the carrier wafer 30 with the laser absorbing release layer LTHC layer is placed on the top chuck 412 and held in place by holding pins 413. Next, the device wafer 20 is placed on the bottom chuck 414 with the adhesive layer 23 facing up. Next, the wafers 20, 30 are aligned, the chamber is evacuated, and the top chuck 412 with the carrier wafer 30 is dropped onto the device wafer 20. A low force is applied for the formation of the bond between the release layer 33 and the adhesive layer 23. Next, the bonded wafer stack 10 is unloaded and the adhesive is cured with UV light.

Referring back to FIG. 3A, the debond process C 80b includes the following steps. The bonded wafer stack 10 is mounted onto a dicing frame 25 (56) and the carrier wafer 30 is illuminated with a YAG laser beam. The laser beam causes the separation of the wafer stack along the release layer 33 (57) and the separated carrier wafer 30 is mechanically lifted away from the device wafer 20 (58). The adhesive layer is peeled away from the device wafer surface 20a (59) and the thinned device wafer 20 remains supported by the dicing frame 25.

Referring to FIG. 5, temporary bonder cluster 110 includes a housing 101 having an upper cabinet structure 102 stacked on top of a lower cabinet 103. The upper cabinet 102 has a service access side 105 and the lower cabinet has leveling adjustments 104 and transport casters 106. Within the upper cabinet structure 102 the configurable temporary bond process modules 210, 310, 410, 510 are vertically stacked, as shown in FIG. 6. Hot plate modules 130 and cold plate modules 140 are also vertically stacked on top, below or in-between the process modules 210, 310, as shown in FIG. 7. Additional process modules may be included in order to provide further processing functionalities. Examples of the bond process modules include low applied force module, high applied force module, high temperature and low temperature modules, illumination (UV light or laser) modules, high pressure (gas) module, low (vacuum) pressure module and combinations thereof.

Referring to FIG. 9 - FIG. 12, temporary bond module 210 includes a housing 212 having a load door 211, an upper block assembly 220 and an opposing lower block assembly 230. The upper and lower block assemblies 220, 230 are movably connected to four Z-guide posts 242. In other embodiments, less than four or more than four Z-guide posts are used. A telescoping curtain seal 235 is disposed between the upper and lower block assemblies 220, 230. A temporary bonding chamber 202 is formed between the upper and lower assemblies 220, 230 and the telescoping curtain seal 235. The curtain seal 235 keeps many of the process components that are outside of the temporary bonding chamber area 202 insulated from the process chamber temperature, pressure, vacuum, and atmosphere. Process components outside of the chamber area 202 include guidance posts 242, Z-axis drive 243, illumination sources, mechanical pre-alignment arms 460a, 460b and wafer centering jaws 461a, 461b, among others. Curtain 235 also provides access to the bond chamber 202 from any radial direction.

Referring to FIG. 11, the lower block assembly 230 includes a heater plate 232 supporting the wafer 20, an insulation layer 236, a water cooled support flange 237 a transfer pin stage 238 and a Z-axis block 239. Heater plate 232 is a ceramic plate and includes resistive heater elements 233 and integrated air cooling 234. Heater elements 233 are arranged so the two different heating zones are formed. A first heating zone 233B is configured to heat a 200 mm wafer or the center region of a 300 mm wafer and a second heating zone 233A is configured to heat the periphery of the 300 mm wafer. Heating zone 233A is controlled independently from heating zone 233B in order to achieve thermal uniformity throughout the entire bond interface 405 and to mitigate thermal losses at the edges of the wafer stack. Heater plate 232 also includes two different vacuum zones for holding wafers of 200 mm and 300 mm, respectively. The water cooled thermal isolation support flange 237 is separated from the heater plate by the insulation layer 236. The transfer pin stage 238 is arranged below the lower block assembly 230 and is movable supported by the four posts 242. Transfer pin stage 238 supports transfer pins 240 arranged so that they can raise or lower different size wafers. In one example, the transfer pins 240 are arranged so that they can raise or lower 200 mm and 300 mm wafers. Transfer pins 240 are straight shafts and, in some embodiments, have a vacuum feed opening extending through their center, as shown in FIG. 15. Vacuum drawn through the transfer pin openings holds the supported wafers in place onto the transfer pins during movement and prevents misalignment of the wafers. The Z-axis block 239 includes a precision Z-axis drive 243 with ball screw, linear cam design, a linear encoder feedback 244 for submicron position control, and a servomotor 246 with a gearbox, shown in FIG. 12.

Referring to FIG. 13, the upper block assembly 220 includes an upper ceramic chuck 222, a top static chamber wall 221 against which the curtain 235 seals with seal element 235a, a 200 mm and a 300 mm membrane layers 224a, 224b, and three metal flexure straps 226 arranged circularly at 120 degrees. The membrane layers 224a, 224b, are clamped between the upper chuck 222 and the top housing wall 213 with clamps 215a, 215b, respectively, and form two separate vacuum zones 223a, 223b designed to hold 200 mm and 300 mm wafers, respectively, as shown in FIG. 14. Membrane layers 224a, 224b are made of elastomer material or metal bellows. The upper ceramic chuck 222 is highly flat and thin. It has low mass and is semi-compliant in order to apply uniform pressure upon the wafer stack 10. The upper chuck 222 is lightly pre-loaded with membrane pressure against three adjustable leveling clamp/drive assemblies 216. Clamp/drive assemblies 216 are circularly arranged at 120 degrees. The upper chuck 222 is initially leveled while in contact with the lower ceramic heater plate 232, so that it is parallel to the heater plate 232. The three metal straps 226 act a flexures and provide X-Y-T (Theta) positioning with minimal Z-constraint for the upper chuck 222. The clamp/drive assemblies 216 also provide a spherical Wedge Error Compensating (WEC) mechanism that rotates and/or tilts the ceramic chuck 222 around a center point corresponding to the center of the supported wafer without translation. In other embodiments, the upper ceramic chuck 222 positioning is accomplished with fixed leveling/locating pins, against which the chuck 222 is lashed.

The loading and pre-alignment of the wafers is facilitated with the mechanical centering device 460, shown in FIG. 16. Centering device 460 includes two rotatable pre-alignment arms 460a, 460b and a linearly moving alignment arm 460c, shown in the open position in FIG. 16 and in the closed position in FIG. 17. At the ends of each arm 460a, 460b there are mechanical jaws 461a, 461b. The mechanical jaws 461a, 461b have tapered surfaces 462 and 463 that conform to the curved edge of the 300 mm wafer and 200 mm wafer, respectively, as shown in FIG. 18A and FIG. 18B.

The linearly moving arm 460c has a jaw 461c with a tapered curved inner surface that also conforms to the curved edge of circular wafers. Rotating arms 460a, 460b toward the center 465 of the support chuck 464 and linearly moving arm 460c toward the center 465 of the support chuck 464 brings the tapered surfaces of the mechanical jaws 461a, 461b and the tapered curved inner surface of jaw 461c in contact with the outer perimeter of the wafer and centers the wafer on the support chuck 464. The three arms 460a, 460b, 460c are arranged at 120 degrees around the support chuck 464. In another embodiment, the centering device 460 includes three rotatable pre-alignment arms, and at the ends of each arm there are mechanical jaws, as shown in FIG. 18A and FIG. 18B. Rotating the arms toward the center of the support chuck 464 brings the tapered surfaces of the mechanical jaws in contact with the outer perimeter of the wafer and centers the wafer on the support chuck 464.

In another embodiment, the loading and pre-alignment of the wafers is facilitated with wafer centering device 470, shown in FIG. 19A and FIG. 19B. Wafer centering device 470 includes three centering linkages 471, 472, 473. Centering linkage 471 includes a rectilinear mid-position air bearing or mechanical slide 471a that moves the wafer 30 in the Y-direction. Centering linkages 472, 473, include rotating centering arms 472a, 473a, that rotate clockwise and counterclockwise, respectively. The motions of the centering linkages 471, 472, 473, are synchronized by the use of a cam plate 474 with two linear cam profiles 474a, 474b. Cam profile 474a provides rectilinear motion for the mid-position centering arm 471 and cam profile 474b provides rectilinear motion for left and right centering arm push rods 472b, 473b. The rectilinear motion of the push rods 472b, 473b, is translated into rotary motion at the cam/cam follower interface at the centering arms 472a, 473a, respectively. The cam plate is 474 fixed to a linear slide that is driven in a rectilinear motion (X-axis motion) by an electric motor or pneumatic actuation. A Linear Variable Differential Transformer (LVDT) or another electrical sensor at the mid-position centering arm 471 mechanism provides distance feedback, which indicates that the centering devices are stopped against the wafer edge. There is a spring preload on the centering device 471a, and when the spring preload is overtaken the LVDT registers a displacement.

In yet another embodiment, the loading and pre-alignment of the wafer 30 is facilitated with wafer centering device 480, shown in FIG. 19C and FIG. 19D. Wafer centering device 400 includes three centering linkages 481, 482, 483. Centering linkage 481 includes a rectilinear mid-position air bearing or mechanical slide 481a that moves the wafer 30 in the Y-direction. Centering linkages 482, 483, include rotating centering arms 482a, 483a, that rotate clockwise and counterclockwise, respectively. The motions of the centering linkages 481, 482, 483, are synchronized by the use of two plates 484, 485 that include linear cam profiles 484a, 484b, respectively. Cam profiles 484a, 485a provide rectilinear motion for left and right centering arm push rods 482, 483, respectively. The rectilinear motion of the push rods 482, 483, is translated into rotary motion at the cam/cam follower interface at the centering arms 486a, 486b, respectively. Plates 484, 485 are connected to linear slide 481a via rods 481a, 481b, respectively. The linear motion of slide 481a in the Y direction is translated via the rods 486a, 486b, into linear motion of plates 484, 485, respectively, along the X-axis, as shown in FIG. 19D.

Referring to FIG. 20A, FIG. 20B, FIG. 20C, the temporary bonding operation with the bonder module 210 includes the following steps. First, the non-adhesive substrate is loaded onto the transfer pins 240a by a robot end effector (350). In this case the substrate is a 300 mm wafer and is supported by the 300 mm pins 240a, whereas the 200 mm pins 240b are shown to be slightly lower than the 300 mm pins 240a. Next, the mechanical taper jaws 461a, 461b, move into position around the wafer and the transfer pins 240a move down (352). The transfer pins have vacuum and purge functions. The purge function allows the wafer to float during the centering cycle and the vacuum function holds the wafer when the centering is complete. The tapered “funnel” jaws 461a, 461b, 461c, drive the wafer to the center as it is lowered via the transfer pins 240a. Jaws 461a, 461b, 461c, are designed to accommodate and pre-align any size wafers, including 200 mm and 300mm, shown in FIG. 19 and 18, respectively. Next, the centering jaws 461a, 461b, 461c retract and the transfer pins move up to place the top substrate 20 on the upper vacuum chuck 222, as shown in FIG. 20C (354). Next, a second adhesive coated substrate 30 is loaded face up onto the transfer pins 240a by the robot end effector (356), shown in FIG. 21A (356). Next, the mechanical taper jaws 460 move into position around the wafer 30 and the transfer pins 240a move down and then up (358), shown in FIG. 21B. The centering jaws 461a, 461b retract and the transfer pins 240a move down to place the substrate 30 on the bottom vacuum chuck 232 (359), shown in FIG. 21C. Next, the lower heater stage 230 moves up to form a close process gap between the top 20 and bottom 30 substrates and the curtain seal 235 is closed to form the temporary bonding chamber 202 (360), shown in FIG. 22A. An initial deep vacuum is drawn (10-4 mbar) in the temporary bonding chamber 202 while the top substrate with 20 is held via mechanical fingers. Once the set vacuum level is reached the chamber pressure is raised slightly to about 5mbar to generate a differential vacuum pressure that holds the top substrate 20 to the upper chuck 222. The Z-axis stage 239 moves further up to bring the bottom substrate 30 in contact with the top substrate 20, a shown in FIG. 22B (362). The top chuck 222 is lifted off from the stops 216 by this motion (362). Next, force is applied via the top membrane 224a and bottom top chuck 232 and the wafer stack 10 is heated to the process temperature (364). In one example, the applied force is in the range between 500 N to 8000N and the process temperature is 200 C. In cases where single sided heating is used, the wafer stack 10 is compressed with the membrane pressure to ensure good thermal transfer. After the end of the treatment, the bonded wafer stack 10 is cooled and unloaded with the help of the transfer pins and the robot end effector (366).

In the above described case, the Z-axis moves up to contact the thin, semi-compliant upper chuck 222/ membrane 224 design. In this embodiment, the adhesive layer controls the TTV/tilt by applying pressure only in the direction perpendicular to the bond interface via the membranes/chuck flexures and by using a semi compliant chuck to conform to the adhesive topography. In other embodiments, the Z-axis moves up to contact a non-compliant chuck. In these cases the Z-axis motion controls the final thickness of the adhesive layer and forces the adhesive to conform to the rigid flat chuck 222. The adhesive layer thickness may be controlled by using a Z-axis position control, pre-measured substrate thicknesses and known adhesive thicknesses. In yet other embodiments, a compliant layer is installed on the bottom chuck 232 and the adhesive is pre-cured or its viscosity is adjusted. In yet other embodiments, heat is applied both through the bottom and top chucks.

Referring to FIG. 23, thermal slide debonder 150 includes a top chuck assembly 151, a bottom chuck assembly 152, a static gantry 153 supporting the top chuck assembly 151, an X-axis carriage drive 154 supporting the bottom chuck assembly 152, a lift pin assembly 155 designed to raise and lower wafers of various diameters including diameters of 200 mm and 300 mm, and a base plate 163 supporting the X-axis carriage drive 154 and gantry 153.

Referring to FIG. 24, the top chuck assembly 151 includes a top support chuck 157 bolted to gantry 153, a heater support plate 158 in contact with the bottom surface of the top support chuck 157, a top heater 159 in contact with the bottom surface of the heater plate 158, a Z-axis drive 160 and a plate leveling system for leveling the upper wafer plate/ heater bottom surface 164. The plate leveling system includes three guide shafts 162 that connect the top heater 159 to the top support chuck 157 and three pneumatically actuated split clamps 161. The plate leveling system provides a spherical Wedge Error Compensating (WEC) mechanism that rotates and/or tilts the upper wafer plate 164 around a center point corresponding to the center of the supported wafer without translation. The heater 159 is a steady state heater capable to heat the supported wafer stack 10 up to 350 °C. Heater 159 includes a first heating zone configured to heat a 200 mm wafer or the center region of a 300 mm wafer and a second heating zone configured to heat the periphery of the 300 mm wafer. The first and second heating zones are controlled independently from each other in order to achieve thermal uniformity throughout the entire bond interface of the wafer stack and to mitigate thermal losses at the edges of the wafer stack. The heater support plate 158 is water cooled in order to provide thermal isolation and to prevent the propagation of any thermal expansion stresses that may be generated by the top heater 159.

Referring to FIG.25, the bottom chuck 152 is made of a low thermal mass ceramic material and is designed to slide along the X-axis on top of the air bearing carriage drive 154. The carriage drive 154 is guided in this X-axis motion by two parallel lateral carriage guidance tracks 156. Bottom chuck 152 is also designed to rotate along its Z-axis 169. A Z-axis rotation by a small angle (i.e., twisting) is used to initiate the separation of the wafers, as will be described below. The base plate 163 is vibration isolated. In one example, base plate is made of granite. In other examples base plate 156 has a honeycomb structure and is supported by pneumatic vibration isolators (not shown).

Referring to FIG. 26A, FIG. 26B, FIG. 26C, the debonding operation with the thermal slide debonder 150 of FIG. 23 includes the following steps. First, the temporary bonded wafer stack 10 is loaded on the primary lift pins 155 arranged so that the carrier wafer 30 is on the top and the thinned device wafer 20 is on the bottom (171). Next, the wafer stack 10 is lowered so that the bottom surface of the thinned device wafer 20 is brought into contact with the bottom chuck 152 (172). The bottom chuck 152 is then moved along the 165a direction until it is under the top heater 159 (174). Next, the Z-axis 160 of the top chuck 151 moves down and the bottom surface 164 of the top heater159 is brought into contact with the top surface of the carrier wafer 30 and then air is floated on top heater 159 and carrier wafer 30 until the carrier wafer stack 30 reaches a set temperature. When the set temperature is reached, vacuum is pulled on the carrier wafer 30 so that is held by the top chuck assembly 151 and the guide shafts 162 are locked in the split clamps 162 (175). At this point the top chuck 151 is rigidly held while the bottom chuck 152 is compliant and the thermal slide separation is initiated (176) by first twisting the bottom chuck 152 and then moving the X-axis carriage 154 toward the 165b direction away from the rigidly held top chuck assembly 151 (177). The debonded thinned device wafer 20 is carried by the X-axis carriage 154 to the unload position where it is lifted up by the pins (178) for removal (179). Next, the X-axis carriage 154 moves back along direction 165a (180). Upon reaching the position under the top chuck assembly 151, the lift pins 155 are raised to contact the adhesive side of the carrier wafer 30 and air is purged onto the heater plate 159 to release the carrier wafer from it (181). The lift pins 155 are lowered to a height just above the bottom chuck plane so as to not contaminated the bottom chuck top surface with the adhesive (182) and the X-axis carriage 154 moves along 165b back to the unload position. The carrier wafer is cooled and then removed (183).

Referring to FIG. 2A, mechanical debonder B 250 debonds the carrier wafer 30 from the thinned device wafer 20 by mechanically lifting an edge 31 of the carrier wafer 30 away from the thinned device wafer 20. Prior to the debonding process the temporary bonded wafer stack 10 is attached to a frame 25, and upon separation the thinned wafer remains supported by the frame 25. Referring to FIG. 27 and FIG. 28, debonder 250 includes a flex plate 253 with a two zone circular vacuum seal 255. Seal 255 includes two zones, one for a sealing a 200 mm wafer placed within the area surrounded by the seal and a second for sealing a 300 mm wafer within the area surrounded by the seal. Seal 255 is implemented either with an O-ring or with suction cups. A lift pin assembly 254 is used to raise or lower the separated carrier wafer 30 that is transported by the flex plate 253. Debonder 250 also includes a vacuum chuck 256. Both the vacuum chuck 256 and the flex plate 253 are arranged next to each other upon a support plate 252, which in turn is supported by the base plate 251. Flex plate 253 has an edge 253b connected to a hinge 263 that is driven by a hinge motor drive 257. Vacuum chuck 256 is made of a porous sintered ceramic material and is designed to support the separated thin wafer 20. Hinge motor drive 257 is used to drive the flex plate 253 upon the wafer stack 10 after the wafer stack 10 has been loaded on the vacuum chuck 256. An anti-backlash gear drive 258 is used to prevent accidental backing of the flex plate 253. A debond drive motor 259 is attached at the edge 251a of the base plate 251 and next to the edge of the chuck support plate 252a. Debond drive motor 259 moves a contact roller 260 vertical to the plane of the base plate 251 in direction 261 and this motion of the contact roller 260 lifts the edge 253a of the flex plate 253 after the flex plate has been placed upon the loaded wafer stack 10, as will be described below.

Referring to FIG. 29, the debonding operation 270 with the debonder 250 includes the following steps. First, The tape frame 25 with the wafer stack 10 is loaded upon the vacuum chuck 256, so that the carrier wafer 30 is on the top and the thinned wafer 20 is on the bottom (271). The tape frame 25 is indexed against the frame registration pins 262, shown in FIG. 28, and the position of the tape frame 25 is locked. Next, vacuum is pulled through the porous vacuum chuck 256 to hold the tape frame adhesive film. Next, the hinge motor 257 is engaged to transport the flex plate 253 onto the loaded wafer stack, so that it is in contact with the back of the carrier wafer 30 (272). Upon reaching the position upon the carrier wafer 30, vacuum is pulled on the carrier wafer top via the seal 255. The torque of the hinge motor 257 is kept constant to maintain the flex plate 253 in this “closed position”. Next, the debond motor 259 is engaged to move the contact roller 260 up in the direction 261a and to push the edge 253a of the flex plate 253 up (273). This upward motion of the flex plate edge 253a bents (or flexes) slightly the carrier wafer 30 and cause the wafer stack 10 to delaminate along the release layer 32 and thereby to separate the carrier wafer 30 from the thinned wafer 20. Silicon wafers break or cleave much easier along the (110) crystallographic plane than any other orientation. Therefore, the carrier wafer 30 is fabricated on a (110) plane so that its 110 direction is perpendicular to the push direction 261a, thereby preventing breaking of the wafer 30 during delamination. The thinned wafer 20 remains attached to the tape frame 25, which is held by the vacuum chuck 256. Through this step the debond motor 259 is held constant in position. Next, the hinge motor drive 257 opens the flex plate 253 with the attached separated carrier wafer 30 in the "open position", in a controlled manner (274). The flex plate vacuum is released thereby releasing the carrier wafer 30. Next, the lift pins 254 are moved up to raise the carrier wafer 30 oriented so that the release layer 32 is facing up and then the carrier wafer 30 is removed. Next, the vacuum through the porous vacuum chuck 256 is released and the tape 25 with the attached thinned wafer 20 is removed.

Several embodiments of the present invention have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the invention. Accordingly, other embodiments are within the scope of the following claims.

What is claimed is:

1. An improved apparatus for temporary bonding and debonding of electronic wafer structures comprising:

a cluster of temporary bonder modules configured to perform electronic wafer bonding processes comprising adhesive layer bonding, combination of an adhesive layer with a release layer bonding and a combination of a UV-light curable adhesive layer with a laser absorbing release layer bonding; and

a cluster of debonder modules configured to perform debonding processes for debonding electronic wafers bonded via the electronic wafer bonding processes performed by the temporary bonder modules, said debonding processes comprising thermal-slide debonding, a mechanical debonding and a radiation debonding.

2. An improved apparatus for temporary bonding and debonding of electronic wafer structures comprising:

a cluster of temporary bonder modules comprising :

first bonder module comprising equipment for forming a temporary bond between two wafer surfaces via an adhesive layer;

second bonder module comprising equipment for forming a temporary bond between two wafer surfaces via a combination of an adhesive layer with a release layer; and

a cluster of debonder modules comprising:

a thermal-slide debonder module comprising equipment for debonding two via an adhesive layer temporary bonded wafers, wherein said equipment comprises means for heating the two bonded wafers and means for sliding one wafer relative to the other while heat is applied ;

a mechanical debonder module comprising equipment for debonding two via a combination of an adhesive layer with a release layer temporary bonded wafers, wherein said equipment comprises means for heating the two bonded wafers and means for mechanically pushing one wafer vertically away from the other while heat is applied.

3. The apparatus of claim 2 wherein said cluster of temporary bonder modules further comprises third bonder module comprising equipment for forming a

temporary bond between two wafer surfaces via a combination of a UV-light curable adhesive layer with a laser absorbing release layer; and

wherein said cluster of debonder modules further comprises a radiation debonder module comprising equipment for debonding two via a combination of a UV-light curable adhesive layer with a laser absorbing release layer temporary bonded wafers, wherein said debonding equipment comprises means for applying laser radiation to the two bonded wafers and means for mechanically separating one wafer away from the other.

4. The apparatus of claim 3 wherein said temporary bonder modules and debonder modules are vertically stacked.

5. The apparatus of claim 2 wherein said first bonder module equipment comprises means for applying said adhesive layer on a surface of a carrier wafer, means for baking and means for chilling said applied adhesive layer, means for applying a protective layer on a surface of a device wafer, means for baking and means for chilling said applied protective layer, means for orienting and aligning the carrier wafer with the device wafer so that the adhesive layer is opposite to the protective layer, means for bringing the aligned carrier wafer in contact with the device wafer thereby forming a stacked wafer pair, means for applying a force onto the stacked wafer pair and means for heating the stacked wafer pair while force is applied, thereby forming a bonded wafer pair.

6. The apparatus of claim 2 wherein said second bonder module equipment comprises means for forming a release layer onto a surface of a device wafer and means for applying a first adhesive layer upon said formed release layer, means for applying a second adhesive layer on a surface of a carrier wafer, means for orienting and aligning the carrier wafer with the device wafer so that the second adhesive layer is opposite to the first adhesive layer, means for bringing the aligned carrier wafer in contact with the device wafer thereby forming a stacked wafer pair, means for applying a force onto the stacked wafer pair and means for heating the stacked wafer pair while force is applied, thereby forming a bonded wafer pair.

7. The apparatus of claim 3 wherein said third bonder module equipment comprises means for applying a UV-light curable adhesive layer onto a surface of a device wafer, means of applying a laser absorbing release layer onto a surface of a carrier wafer, means for orienting and aligning the carrier wafer with the device wafer so that the laser absorbing release layer is opposite to the UV-light curable adhesive layer, means for bringing the aligned carrier wafer in contact with the device wafer thereby forming a stacked wafer pair, means for applying a force onto the stacked wafer pair and means for applying UV-light to the stacked wafer pair while force is applied, thereby forming a bonded wafer pair.

8. The apparatus of claim 3 wherein any of said bonder modules comprises:

an upper block assembly;

a lower block assembly arranged below and opposite the upper block assembly;

a telescoping curtain disposed between the upper and lower block assembly and surrounding and sealing a volume between the upper block assembly and the lower block assembly, wherein said sealed volume defines a temporary bonding chamber containing said first bonder module equipment; and

means for evacuating said temporary bonding chamber; and

means for providing a gas into said temporary bonding chamber.

9. The apparatus of claim 8 wherein any of said bonder modules further comprises two or more Z-guide posts and wherein said upper and lower block assemblies are movably connected to said Z-guide posts.

10. The apparatus of claim 8 wherein said lower block assembly comprises:

a heater plate having top and bottom surfaces and wherein said heater plate top surface is configured to support and heat a first wafer;

an insulation layer having top and bottom surfaces and wherein said insulation layer top surface in contact with said heater plate bottom surface;

a cooled support flange having top and bottom surfaces and wherein said cooled support flange top surface is in contact with said insulation layer bottom surface;

a transfer pin stage arranged below said cooled support flange and supporting three or more transfer pins passing through said cooled support flange, said insulation layer and said heater plate and configured to raise and lower said first wafer; and

a Z-axis block drive comprising a precision Z-drive and a linear encoder feedback for submicron position control and wherein said Z-axis block drive is configured to move said lower block assembly up and down in the Z-direction.

11. The apparatus of claim 10 wherein said heater plate comprises two independently controlled concentric heating zones configured to heat wafers having a diameter of 200 or 300 millimeters, respectively.

12. The apparatus of claim 11 wherein said heater plate further comprises two independently controlled concentric vacuum zones configured to hold wafers having a diameter of 200 or 300 millimeters, respectively, onto the heater plate top surface.

13. The apparatus of claim 8 wherein said upper block assembly comprises:

an upper ceramic chuck configured to hold a second wafer and wherein said upper ceramic chuck comprises a highly flat, thin, semi-compliant ceramic plate;

a static chamber wall against which said telescoping curtain forms a seal with a sealing element;

first and second concentric membrane layers having a diameter of 200 and 300 millimeters, respectively, and being clamped between said upper chuck and a top housing wall, and wherein said first and second membrane layer form separate first and second vacuum zones designed to hold wafers having 200 and 300 millimeters, respectively;

three or more adjustable leveling clamp/drive assemblies configured to level and clamp the upper ceramic chuck against the top housing wall.

14. The apparatus of claim 13 wherein said membrane layers comprise one of elastomeric materials or metal bellows.

15. The apparatus of claim 14 wherein said clamp/drive assemblies further comprise a wedge error compensation mechanism that rotates and/or tilts the upper ceramic chuck around a center point corresponding to the center of the held second wafer without translation.

16. The apparatus of claim 8 further comprising a mechanical centering device configured to pre-align, load and unload said first and second wafers in any of said bonder modules.

17. The apparatus of claim 16 wherein said mechanical centering device comprises:

two pre-alignment arms and wherein each pre-alignment arm comprises a mechanical jaw at its first end, said mechanical jaw comprising a tapered surface conforming to the curved edge of said first and second wafers; and

a stationary jaw having a tapered surface conforming to the curved edge of said first and second wafers.

18. A method for temporary bonding two wafer surfaces comprising:

providing a first wafer comprising first and second wafer surfaces opposite to each other;

providing a second wafer comprising first and second wafer surfaces opposite to each other;

applying an adhesive layer upon said first surface of said second wafer;

providing a bonder module comprising an upper block assembly; a lower block assembly arranged below and opposite the upper block assembly; a telescoping curtain disposed between the upper and lower block assembly and surrounding and sealing a volume between the upper block assembly and the lower block assembly, wherein said sealed volume defines a temporary bonding chamber; means for evacuating said temporary bonding chamber means for providing a gas into said temporary bonding chamber;

inserting said first wafer into said bonder module and holding said first wafer by said upper block assembly so that its first surface faces down;

inserting said second wafer into said bonder module and placing said second wafer upon said lower block assembly so that said adhesive layer is opposite to said first wafer's first surface;

centering and aligning said first and second wafers so that said first wafer's first surface is opposite and parallel to said adhesive layer of said second wafer;

moving said lower block assembly upward to form a close process gap between said adhesive layer and said first surface of said first wafer;

closing said telescoping curtain and thereby forming a temporary bonding chamber surrounding said first and second wafers;

evacuating said temporary bonding chamber to an initial deep vacuum while said first wafer is held via mechanical jaws;

upon reaching said initial deep vacuum, providing a gas into said temporary bonding chamber to slightly raise said temporary bonding chamber pressure above said initial deep vacuum, thereby generating a differential pressure that holds said first wafer in contact with said upper block assembly;

moving the lower block assembly upward to bring the adhesive layer in contact with the first surface of the first wafer;

applying a force to the first and second wafers via the upper block assembly while heating the first and second wafers to a process temperature above the melting point of said adhesive layer thereby forming a temporary bonded wafer pair;

cooling the bonded wafer pair and unloading it from the bonder module.

19. The method of claim 18 wherein said upper block assembly comprises a semi-compliant chuck and wherein said force is applied perpendicular to the bond interface of the first and second wafers via said semi-compliant chuck.

20. The method of claim 18 wherein said upper block comprises a non-compliant chuck and wherein said method further comprises controlling the final thickness of the adhesive layer in the bonded wafer pair via the upward motion of said lower block assembly.

21. An improved apparatus for temporary bonding of electronic wafer structures comprising:

first bonder module comprising equipment for forming a temporary bond between two wafer surfaces via an adhesive layer;

second bonder module comprising equipment for forming a temporary bond between two wafer surfaces via a combination of an adhesive layer with a release layer; and

third bonder module comprising equipment for forming a temporary bond between two wafer surfaces via a combination of a UV-light curable adhesive layer with a laser absorbing release layer.

22. A debonder apparatus for debonding two via an adhesive layer temporary bonded wafers, comprising:

a top chuck assembly comprising a heater and a wafer holder;

a bottom chuck assembly;

a static gantry supporting the top chuck assembly;

an X-axis carriage drive supporting the bottom chuck assembly;

an X-axis drive control configured to drive horizontally the bottom chuck assembly from a loading zone to a process zone under the top chuck assembly and from the process zone back to the loading zone;

wherein a wafer pair comprising a carrier wafer bonded to a device wafer via an adhesive layer is placed upon said bottom chuck assembly at the loading zone oriented so that the unbonded surface of the device wafer is in contact with the bottom assembly and is carried by said X-axis carriage drive to the process zone under the top chuck assembly and the unbonded surface of the carrier wafer is placed in contact with the top chuck assembly; and

wherein said X-axis drive control initiates horizontal motion of said X-axis carriage drive along the X-axis while said bonded wafer pair is heated via said heater to a temperature around or above said adhesive layer's melting point and while said carrier wafer is held by said top chuck assembly via said wafer holder and said device wafer is held by said bottom assembly and thereby causes the device wafer to separate and slide away from the carrier wafer.

23. The debonder of claim 22 further comprising a lift pin assembly designed to raise and lower wafers placed on the bottom chuck assembly.

24. The debonder of claim 22 further comprising a base plate supporting the X-axis carriage drive and the static gantry.

25. The debonder of claim 24 wherein said base plate comprises a honeycomb structure and vibration isolation supports.

26. The debonder of claim 24 wherein said base plate comprises a granite plate.

27. The debonder of claim 22 wherein said bottom chuck assembly comprises a bottom chuck comprising a low thermal mass ceramic material and is designed to slide horizontally along the X-axis upon said X-axis carriage drive and to twist around the Z-axis.

28. The debonder of claim 22 wherein said X-axis carriage drive comprises an air bearing carriage drive.

29. The debonder of claim 22 further comprising two parallel lateral carriage guidance tracks guiding said X-axis carriage drive in its horizontal motion along the X-axis.

30. The debonder of claim 22, wherein said top chuck assembly further comprises:

a top support chuck bolted to the static gantry;

a heater support plate in contact with the bottom surface of the top support chuck;

said heater being in contact with the bottom surface of the heater support plate;

a top wafer plate in contact with the heater;

a Z-axis drive for moving the top wafer plate in the Z-direction and placing the top wafer plate in contact with the unbonded surface of the carrier wafer; and

a plate leveling system for leveling the top wafer plate and for providing wedge error compensation of the top wafer plate.

31. The debonder of claim 30 wherein said wafer holder comprises vacuum pulling said carrier wafer.

32. The debonder of claim 30 wherein said plate leveling system comprises three guide shafts connecting said heater to said top support chuck and three pneumatically actuated split clamps.

33. The debonder of claim 30 wherein said heater comprises two independently controlled concentric heating zones configured to heat wafers having a diameter of 200 or 300 millimeters, respectively.

34. A method for debonding two via an adhesive layer temporary bonded wafers, comprising:

providing a bonder comprising a top chuck assembly, a bottom chuck assembly, a static gantry supporting the top chuck assembly, an X-axis carriage drive supporting the bottom chuck assembly and an X-axis drive control configured to drive horizontally the X-axis carriage drive and the bottom chuck assembly from a loading zone to a process zone under the top chuck assembly and from the process zone back to the loading zone;

loading a wafer pair comprising a carrier wafer bonded to a device wafer via an adhesive layer upon said bottom chuck assembly at the loading zone oriented so that the unbonded surface of the device wafer is in contact with the bottom assembly;

driving said X-axis carriage drive and said bottom chuck assembly to the process zone under the top chuck assembly;

placing the unbonded surface of the carrier wafer in contact with the top chuck assembly and holding said carrier wafer by said top chuck assembly;

heating said carrier wafer with a heater comprised in said top chuck assembly to a temperature around or above said adhesive layer's melting point;

initiating horizontal motion of said X-axis carriage drive along the X-axis by said X-axis drive control while heat is applied to said carrier wafer and while said carrier wafer is held by said top chuck assembly and said device wafer is held by said bottom chuck assembly and thereby causing the device wafer to separate and slide away from the carrier wafer.

35. The method of claim 34 further comprising raising and lowering said wafer pair onto the bottom chuck assembly via a lift pin assembly.

36. The method of claim 34 wherein said bonder further comprises a base plate supporting the X-axis carriage drive and the static gantry.

37. The method of claim 36 wherein said base plate comprises a honeycomb structure and vibration isolation supports.

38. The method of claim 36 wherein said base plate comprises a granite plate.

39. The method of claim 34 further comprising twisting the device wafer at the same time said horizontal motion is initiated.

40. The method of claim 34 wherein said X-axis carriage drive comprises an air bearing carriage drive.

41. The method of claim 34 wherein said debonder further comprises two parallel lateral carriage guidance tracks guiding said X-axis carriage drive in its horizontal motion along the X-axis.

42. The method of claim 34, wherein said top chuck assembly further comprises:

a top support chuck bolted to the static gantry;

a heater support plate in contact with the bottom surface of the top support chuck;

said heater being in contact with the bottom surface of the heater support plate;

a top wafer plate in contact with the heater;

a Z-axis drive for moving the top wafer plate in the Z-direction and placing the top wafer plate in contact with the unbonded surface of the carrier wafer; and

a plate leveling system for leveling the top wafer plate and for providing wedge error compensation of the top wafer plate.

43. The method of claim 34 wherein said carrier wafer is held by said top chuck assembly via vacuum pulling.

44. The method of claim 34, wherein said plate leveling system comprises three guide shafts connecting said heater to said top support chuck and three pneumatically actuated split clamps.

45. The method of claim 34, wherein said heater comprises two independently controlled concentric heating zones configured to heat wafers having a diameter of 200 or 300 millimeters, respectively.

46. A debonder apparatus for debonding two via an adhesive layer combined with a release layer temporary bonded wafers, comprising:

a chuck assembly comprising a chuck and a first wafer holder configured to hold wafers in contact with the top surface of the chuck;

a flex plate assembly comprising a flex plate and a second wafer holder configured to hold wafers in contact with a first surface of the flex plate, wherein said flex plate comprises a first edge connected to a hinge and a second edge diametrically opposite to the first edge, and wherein said flex plate's first edge is arranged adjacent to a first edge of the chuck and said flex plate is configured to swing around said hinge and to be placed above the top surface of the chuck;

a contact roller arranged adjacent to a second edge of the chuck, said second edge of the chuck being diametrically opposite to its first edge;

a debond drive motor configured to move the contact roller vertical to the plane of the chuck top surface;

wherein a wafer pair, comprising a carrier wafer stacked upon and being bonded to a device wafer via an adhesive layer and a release layer, is placed upon said chuck so that the ubonded surface of the device wafer is in contact with the chuck top surface;

wherein said flex plate swings around said hinge and is placed above said bottom chuck so that its first surface is in contact with the unbonded surface of the carrier wafer;

wherein said contact roller is driven upward until it contacts and pushes the second edge of the flex plate up while said carrier wafer is held by said flex plate and said device wafer is held by said chuck via said second and first wafer holders, respectively; and

wherein said contact roller push flexes said second edge of the flex plate and causes delamination of the wafer pair along the release layer.

47. The debonder of claim 46 further comprising a hinge motor and wherein said hinge is driven by said hinge motor.

48. The debonder of claim 46, wherein said first and second holders comprise vacuum pulling through the chuck and the flex plate, respectively.

49. The debonder of claim 46, wherein said wafer pair further comprises a tape frame and said device wafer is held by said chuck by holding said tape frame via the vacuum pulled through the chuck.

50. The debonder of claim 46, further comprising a support plate supporting said chuck assembly, said flex plate assembly and said hinge.

51. The debonder of claim 50, further comprising a base plate supporting said support plate, said contact roller, said hinge motor and said debond drive motor.

52. The debonder of claim 46, wherein said flex plate assembly further comprises a lift pin assembly designed to raise and lower wafers placed on the first surface of the flex plate.

53. The debonder of claim 46, wherein said flex plate further comprises two independently controlled concentric vacuum zones configured to hold wafers having a diameter of 200 or 300 millimeters, respectively.

54. The debonder of claim 53, wherein said vacuum zones are sealed via one of an O-ring or suction cups.

55. The debonder of claim 54, wherein said chuck comprises a vacuum chuck made of porous ceramic materials.

56. The debonder of claim 46 further comprising an anti-backlash gear drive configured to prevent accidental back swing of the flex pate.

57. A method for debonding two via an adhesive layer combined with a release layer temporary bonded wafers, comprising:

providing a debond apparatus comprising a chuck assembly, a flex plate assembly and a contact roller, wherein said chuck assembly comprises a chuck and a first wafer holder configured to hold wafers in contact with the top surface of the chuck, wherein said flex plate assembly comprises a flex plate and a second wafer holder configured to hold wafers in contact with a first surface of the flex plate, wherein said flex plate comprises a first edge connected to a hinge and a second edge diametrically opposite to the first edge, and wherein said flex plate's first edge is arranged adjacent to a first edge of the chuck and said flex plate is configured to swing around said hinge and to be placed above the top surface of the chuck and wherein said contact roller is arranged adjacent to a second edge of the chuck, said second edge of the chuck being diametrically opposite to its first edge;

providing a wafer pair comprising a carrier wafer stacked upon and being bonded to a device wafer via an adhesive layer and a release layer;

placing said wafer pair upon said chuck so that the ubonded surface of the device wafer is in contact with the chuck top surface;

swinging said flex plate around said hinge and placing it above said bottom chuck so that its first surface is in contact with the unbonded surface of the carrier wafer;

driving said contact roller upward until it contacts and pushes the second edge of the flex plate up while said carrier wafer is held by said flex plate and said device wafer is held by said chuck via said second and first wafer holders, respectively; and

wherein said contact roller push flexes said second edge of the flex plate and causes delamination of the wafer pair along the release layer.

58. The method of claim 57 wherein said debond apparatus further comprises a debond drive motor configured to move the contact roller vertical to the plane of the chuck top surface.

59. The method of claim 57 wherein said debonder apparatus further comprises a hinge motor and wherein said hinge is driven by said hinge motor.

60. The method of claim 57 wherein said first and second holders comprise vacuum pulling through the chuck and the flex plate, respectively.

61. The method of claim 57 wherein said wafer pair further comprises a tape

frame and said device wafer is held by said chuck by holding said tape frame via the vacuum pulled through the chuck.

62. The method of claim 57 wherein said debonder apparatus further comprises a support plate supporting said chuck assembly, said flex plate assembly and said hinge.

63. The method of claim 57 wherein said debonder apparatus further comprises a base plate supporting said support plate, said contact roller, said hinge motor and said debond drive motor.

64. The method of claim 57 wherein said flex plate assembly further comprises a lift pin assembly designed to raise and lower wafers placed on the first surface of the flex plate.

65. The method of claim 57 wherein said flex plate further comprises two independently controlled concentric vacuum zones configured to hold wafers having a diameter of 200 or 300 millimeters, respectively.

66. The method of claim 65 wherein said vacuum zones are sealed via one of an O-ring or suction cups.

67. The method of claim 66 wherein said chuck comprises a vacuum chuck made of porous ceramic materials.

68. The method of claim 57 wherein said debonder apparatus further comprises an anti-backlash gear drive configured to prevent accidental back swing of the flex pate.

69. A device for centering circular wafers, comprising:

a support chuck for supporting a circular wafer to be centered upon its top surface;

first rotationally movable alignment arm being rotatable around an axis perpendicular to the top surface of the support chuck and comprising a first mechanical jaw, said first mechanical jaw comprising a tapered curved edge surface conforming to the curved edge of the circular wafer;

second rotationally movable alignment arm being rotatable around an axis perpendicular to the top surface of the support chuck and comprising a second mechanical jaw, said second mechanical jaw comprising a tapered curved edge surface conforming to the curved edge of the circular wafer;

third linear moving alignment arm comprising a tapered curved inner surface conforming to the curved edge of the circular wafer;

wherein said first, second and third alignment arms are arranged around the support chuck at an angle of 120 degrees from each other; and

wherein a circular wafer placed on the support chuck is centered and aligned by rotating the first and second alignment arms toward the center of the support chuck so that the tapered curved edge surfaces of the first and second mechanical jaws contact the outer perimeter of the circular wafer at first and second perimeter areas, respectively, and by linearly moving the third alignment arm toward the center of the support chuck so that its tapered curved inner surface contacts the outer perimeter of the circular wafer at third perimeter area, and wherein said first, second and third perimeter areas are separated by an angle of 120 degrees from each other.

70. The device of claim 69 wherein said mechanical jaws comprise a first tapered curved edge surface conforming to the curved edge of a circular wafer having a diameter of 200 millimeters and a second tapered curved edge surface conforming to the curved edge of a circular wafer having a diameter of 300 millimeters.

71. A device for centering circular wafers, comprising:

a support chuck for supporting a circular wafer to be centered upon its top surface;

first rotationally movable alignment arm being rotatable around an axis perpendicular to the top surface of the support chuck and comprising a first mechanical jaw, said first mechanical jaw comprising a tapered curved edge surface conforming to the curved edge of the circular wafer;

second rotationally movable alignment arm being rotatable around an axis perpendicular to the top surface of the support chuck and comprising a second mechanical jaw, said second mechanical jaw comprising a tapered curved edge surface conforming to the curved edge of the circular wafer;

third rotationally movable alignment arm being rotatable around an axis perpendicular to the top surface of the support chuck and comprising a third mechanical jaw, said third mechanical jaw comprising a tapered curved edge surface conforming to the curved edge of the circular wafer;

wherein said first, second and third alignment arms are arranged around the support chuck at an angle of 120 degrees from each other; and

wherein a circular wafer placed on the support chuck is centered and aligned by rotating the first, second and third alignment arms toward the center of the support chuck so that the tapered curved edge surfaces of the first, second and third mechanical jaws contact the outer perimeter of the circular wafer at first, second and third perimeter areas, respectively, and wherein said first, second and third perimeter areas are separated by an angle of 120 degrees from each other.

72. The device of claim 71 wherein said mechanical jaws comprise a first tapered curved edge surface conforming to the curved edge of a circular wafer having a diameter of 200 millimeters and a second tapered curved edge surface conforming to the curved edge of a circular wafer having a diameter of 300 millimeters.

73. A device for centering circular wafers, comprising:

a support chuck for supporting a circular wafer to be centered upon its top surface;

left centering linkage rod comprising a first rotating arm at a first end, and wherein rectilinear motion of the left centering linkage rod translates into rotational motion of the first rotating arm, and wherein said first rotating arm is rotatable around an axis perpendicular to the top surface of the support chuck and comprises a curved edge surface configured to roll against the curved edge of the circular wafer;

right centering linkage rod comprising a second rotating arm at a first end, and wherein rectilinear motion of the right centering linkage rod translates into rotational motion of the second rotating arm, and wherein said second rotating arm is rotatable around an axis perpendicular to the top surface of the support chuck and comprises a curved edge surface configured to roll against the curved edge of the circular wafer;

middle centering linkage rod comprising a third alignment arm at a first end, wherein said third alignment arm is placed in contact with the curved edge of the circular wafer and wherein linear motion of the middle centering linkage rod in the Y-direction pushes the third alignment arm and the circular wafer toward or away from the center of the support chuck; and

a cam plate synchronizing the rectilinear motions of the left, right and middle centering linkage rods, said cam plate comprising first and second linear cam profiles, wherein said first cam profile provides rectilinear motion for the middle centering linkage rod and said second linear cam profile provides rectilinear motion for the left and right centering linkage rods.

74. The device of claim 73 wherein said first and second cam linear profiles comprise surfaces arranged at an angle relative to each other and relative to the Y-direction.

75. The device of claim 73 further comprising a connection rod attached to second ends of the left and right centering linkage rods and wherein said connection rod is configured to roll along the second linear cam profile of the cam plate.

76. The device of claim 73 wherein said middle centering linkage rod comprises a roller at a second end and said roller is configured to roll along the first linear cam profile of the cam plate

77. The device of claim 73 further comprising a motor and a linear slide and wherein said cam plate is fixed to the linear slide and said motor provides rectilinear motion to the linear slide and thereby to the cam plate.

78. The device of claim 73 further comprising a sensor indicating that the first, second and third alignment arms are in contact with the curved edge of the circular wafer.

79. The device of claim 78 wherein said sensor comprise one of a linear variable differential transformer (LVDT) or an electric sensor.

80. A device for centering circular wafers, comprising:

a support chuck for supporting a circular wafer to be centered upon its top surface;

left centering linkage rod comprising a first rotating arm at a first end, and wherein rectilinear motion of the left centering linkage rod translates into rotational motion of the first rotating arm, and wherein said first rotating arm is rotatable around an axis perpendicular to the top surface of the support chuck and comprises a curved edge surface configured to roll against the curved edge of the circular wafer;

right centering linkage rod comprising a second rotating arm at a first end, and wherein rectilinear motion of the right centering linkage rod translates into wise rotational motion of the second rotating arm, and wherein said second rotating arm is rotatable around an axis perpendicular to the top surface of the support chuck and comprises a curved edge surface configured to roll against the curved edge of the circular wafer;

middle centering linkage rod comprising a third alignment arm at a first end, wherein said third alignment arm is placed in contact with the curved edge of the circular wafer and wherein linear motion of the middle centering linkage rod in the Y-direction pushes the third alignment arm and the circular wafer toward or away from the center of the support chuck; and

first and second cam plates synchronizing the rectilinear motions of the left, right and middle linkage rods, said first and second cam plates comprising first and second linear cam profiles, respectively, wherein said first cam profile provides rectilinear motion for the left centering linkage rod and said second cam profile provides rectilinear motion for the right linkage rod.

81. The device of claim 80 further comprising:

a linear slide connected to a second end of the middle centering linkage rod and providing linear motion in the Y-direction to the middle centering linkage rod; and

wherein said first and second cam plates are connected to said linear slide via first and second connection rods, respectively, and linear motion of the linear slide in the Y-direction is translated into linear motion of the first and second cam plates in the X-direction.

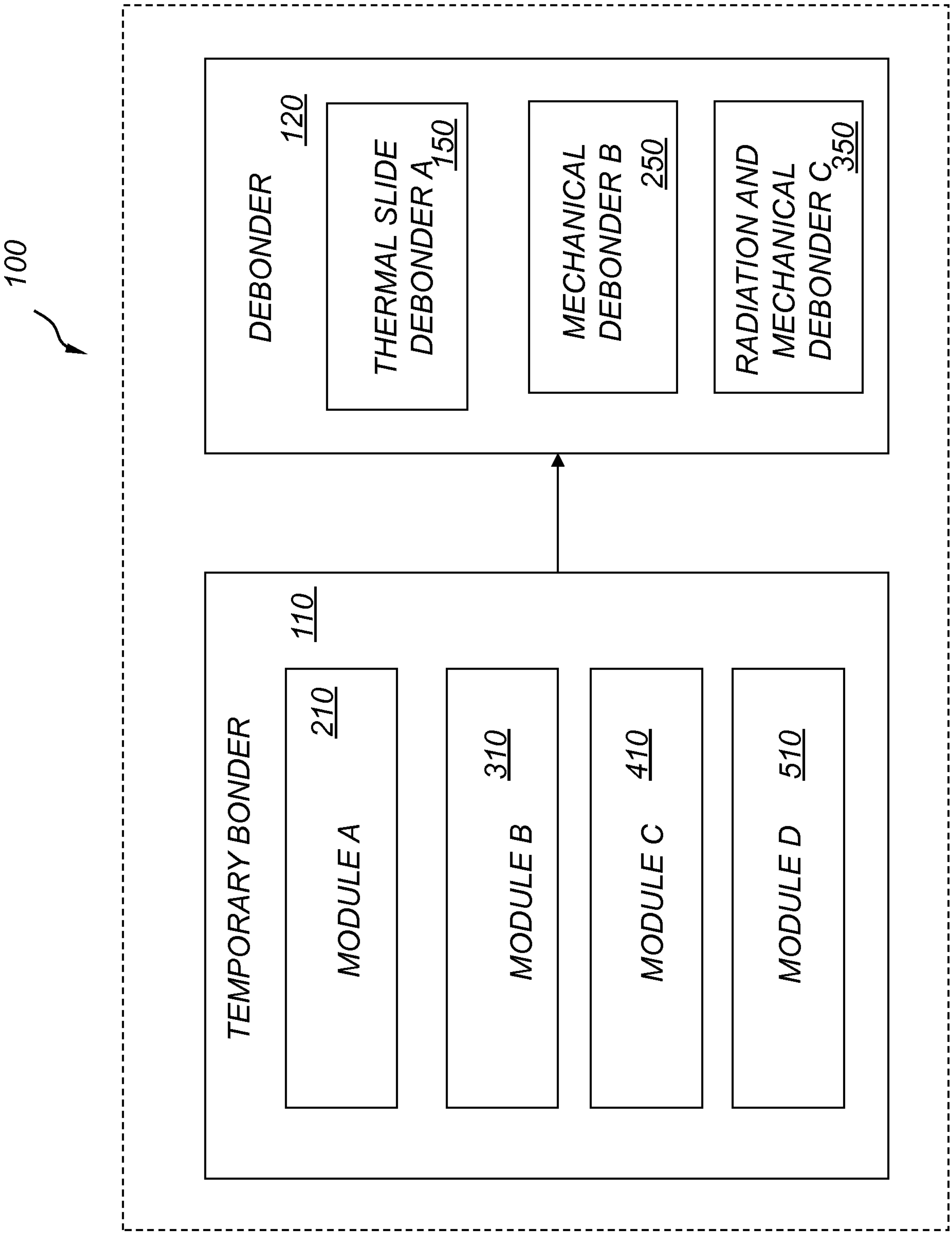

100
DEBONDER 120
THERMAL SLIDE DEBONDER A 150
MECHANICAL DEBONDER B 250
RADIATION AND MECHANICAL DEBONDER C 350
TEMPORARY BONDER 110
MODULE A 210
MODULE B 310
MODULE C 410
MODULE D 510

FIG. 1

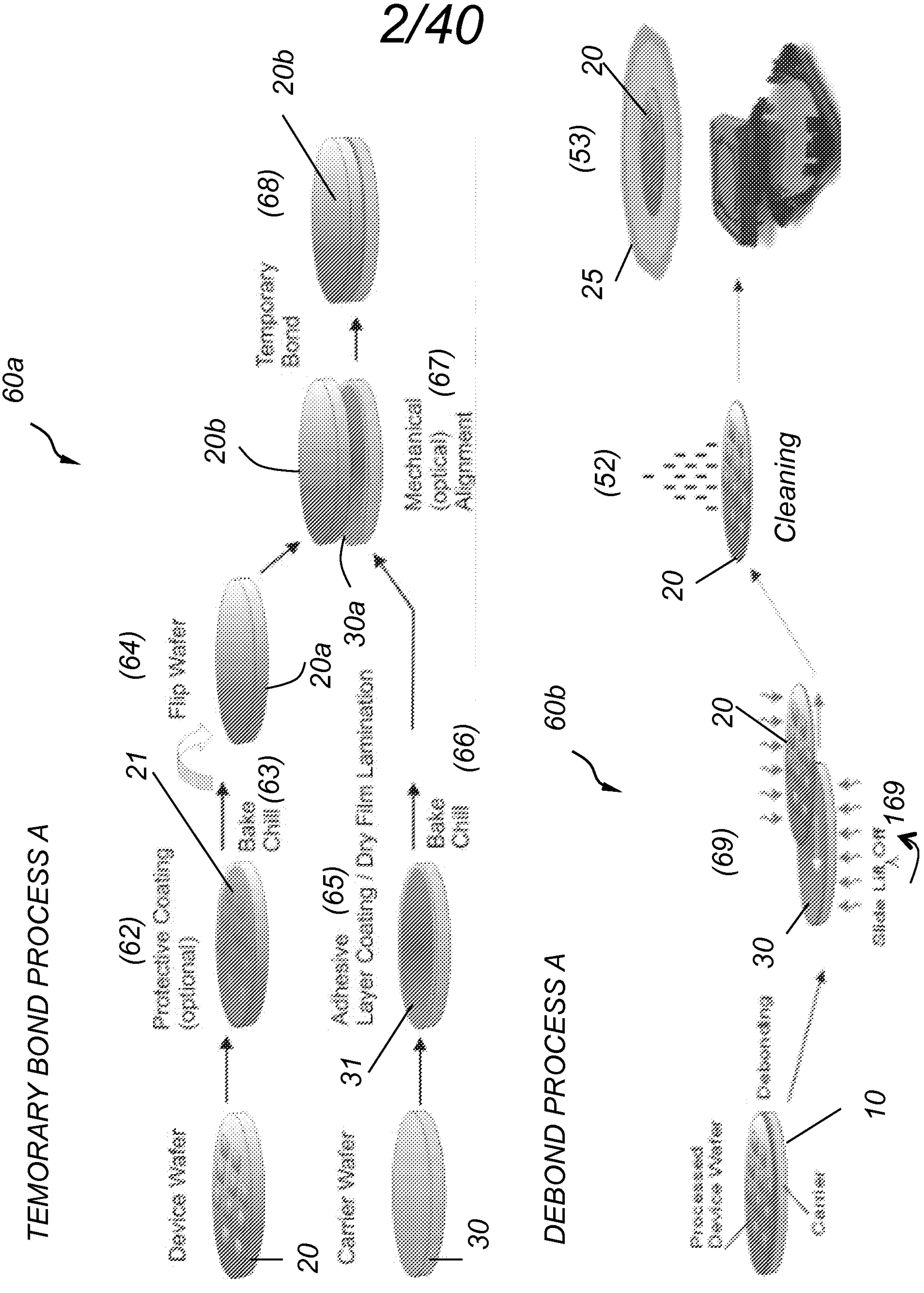
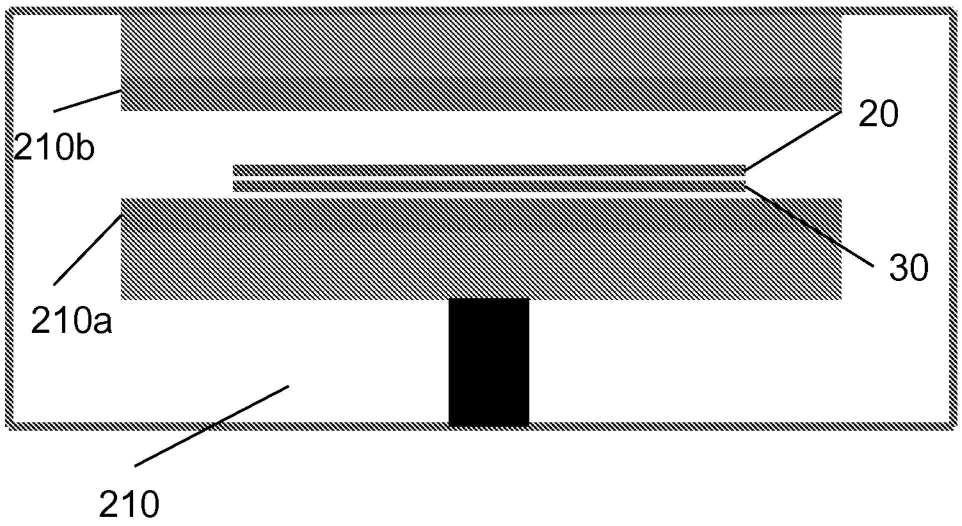

TEMORARY BOND PROCESS A
60a
Device Wafer
20
(62)
Protective Coating (optional)
21
Bake Chill (63)
(64)
Flip Wafer
20a
20b
30a
Mechanical (optical) Alignment (67)
Temporary Bond
(68)
20b
Carrier Wafer
30
31
(65)
Adhesive Layer Coating / Dry Film Lamination
Bake Chill
(66)
DEBOND PROCESS A
60b
Processed Device Wafer
Carrier
10
Debonding
30
(69)
Slide Lift Off
169
20
20
(52)
Cleaning
25
(53)
20

FIG. 1A



- Process Basics
  - Place bottom wafer on fixture chuck
  - Place top adhesive carrier direct
  - Manual Align
  - Load into chamber
  - Top chuck down, force
  - Vacuum pump down
  - Heat to ~200C
  - Cool to unload temp
  - Unload fixture

FIG. 1B

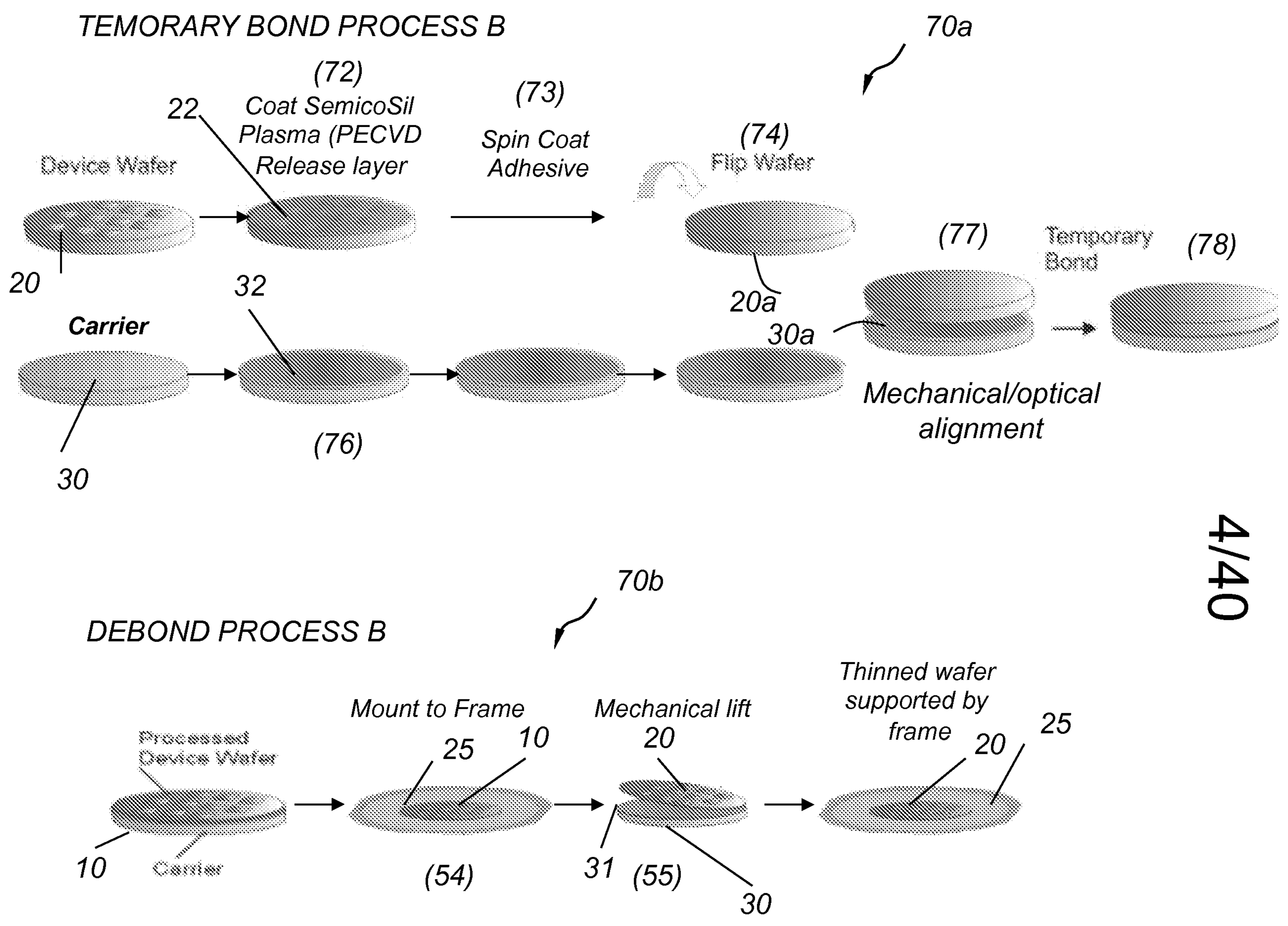
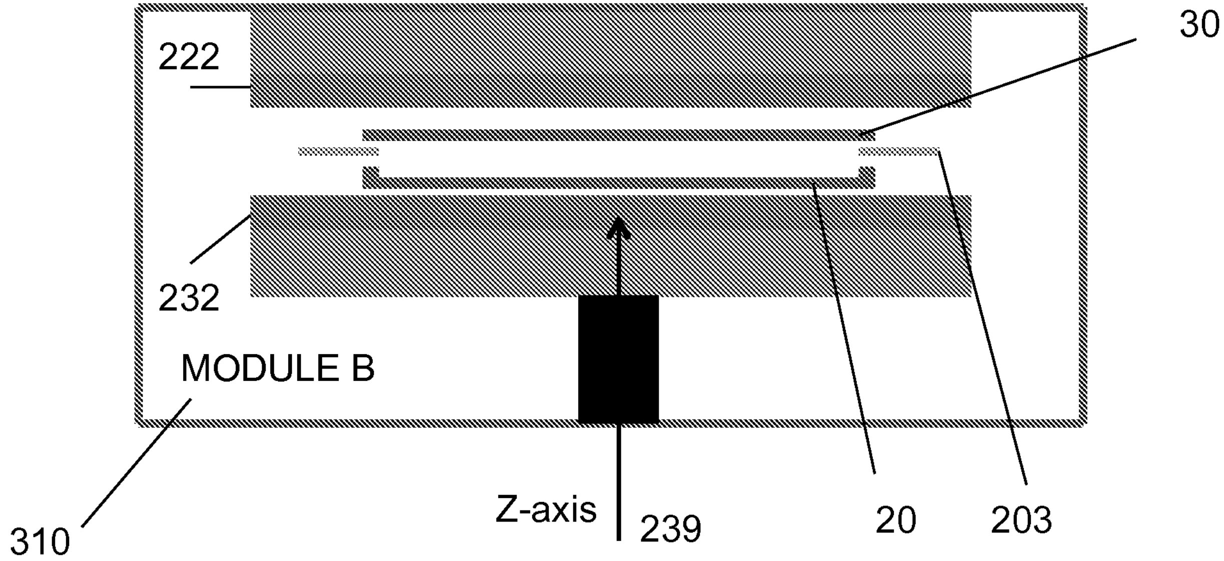

TEMORARY BOND PROCESS B
70a
(72)
Coat SemicoSil
Plasma (PECVD
Release layer
(73)
Spin Coat
Adhesive
(74)
Flip Wafer
Device Wafer
22
20
32
Carrier
20a
30a
(77)
Temporary
Bond
(78)
Mechanical/optical
alignment
(76)
30
DEBOND PROCESS B
70b
Processed
Device Wafer
Carrier
10
Mount to Frame
25
10
(54)
Mechanical lift
20
31
(55)
30
Thinned wafer
supported by
frame
20
25

FIG. 2A



- Process Basics
  - Place bottom adhesive carrier on fixture
  - Place top wafer on spacer flags
  - Manual Align
  - Load into chamber
  - Vacuum pump down
  - Remove spacers, drop wafer to edge bead
  - Purge chamber (force)
  - Heat to ~200C
  - Cool to unload temp
  - Unload fixture

FIG. 2B

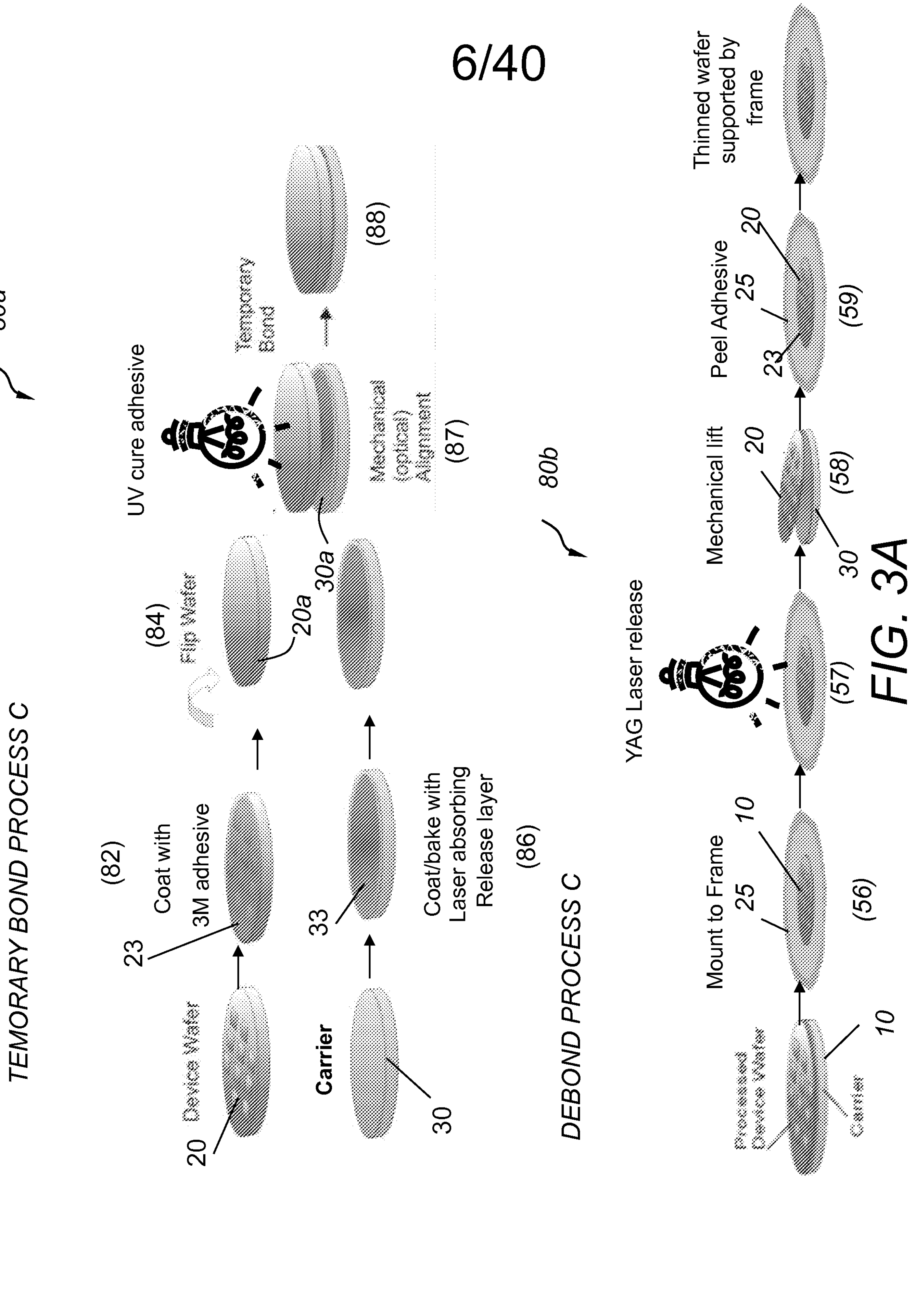

TEMORARY BOND PROCESS C
80a
20
Device Wafer
23
(82)
Coat with
3M adhesive
(84)
Flip Wafer
20a
30a
UV cure adhesive
Mechanical
(optical)
Alignment
(87)
Temporary
Bond
(88)
Carrier
30
33
Coat/bake with
Laser absorbing
Release layer
(86)
DEBOND PROCESS C
80b
Processed
Device Wafer
Carrier
10
Mount to Frame
25
10
(56)
YAG Laser release
(57)
Mechanical lift
20
30
(58)
Peel Adhesive
23
25
20
(59)
Thinned wafer
supported by
frame

FIG. 3A

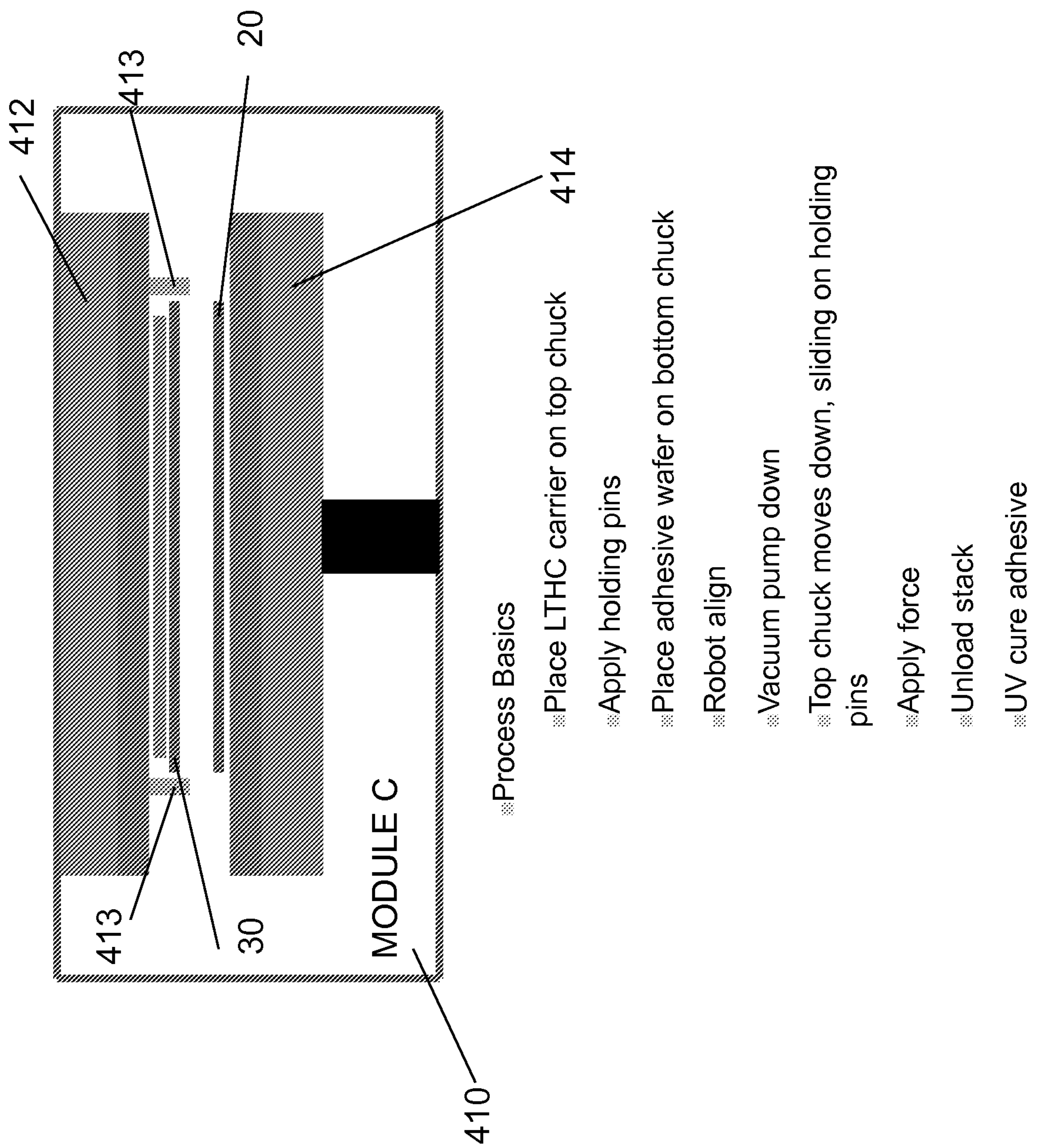

412
413
20
414
413
30
MODULE C
410
Process Basics
Place LTHC carrier on top chuck
Apply holding pins
Place adhesive wafer on bottom chuck
Robot align
Vacuum pump down
Top chuck moves down, sliding on holding pins
Apply force
Unload stack
UV cure adhesive

FIG. 3B

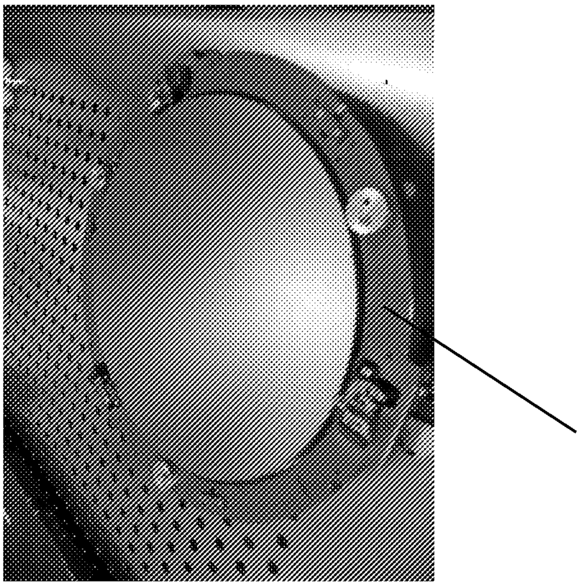


FIG. 4

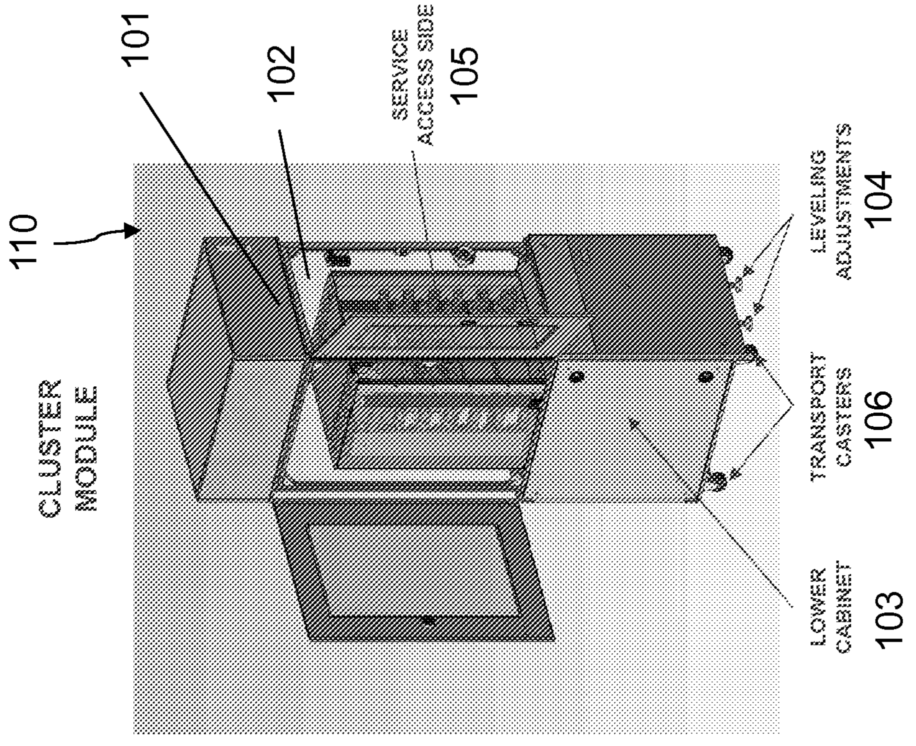

CLUSTER MODULE
110
101
102
SERVICE ACCESS SIDE
105
LEVELING ADJUSTMENTS
104
TRANSPORT CASTERS
106
LOWER CABINET
103

FIG. 5

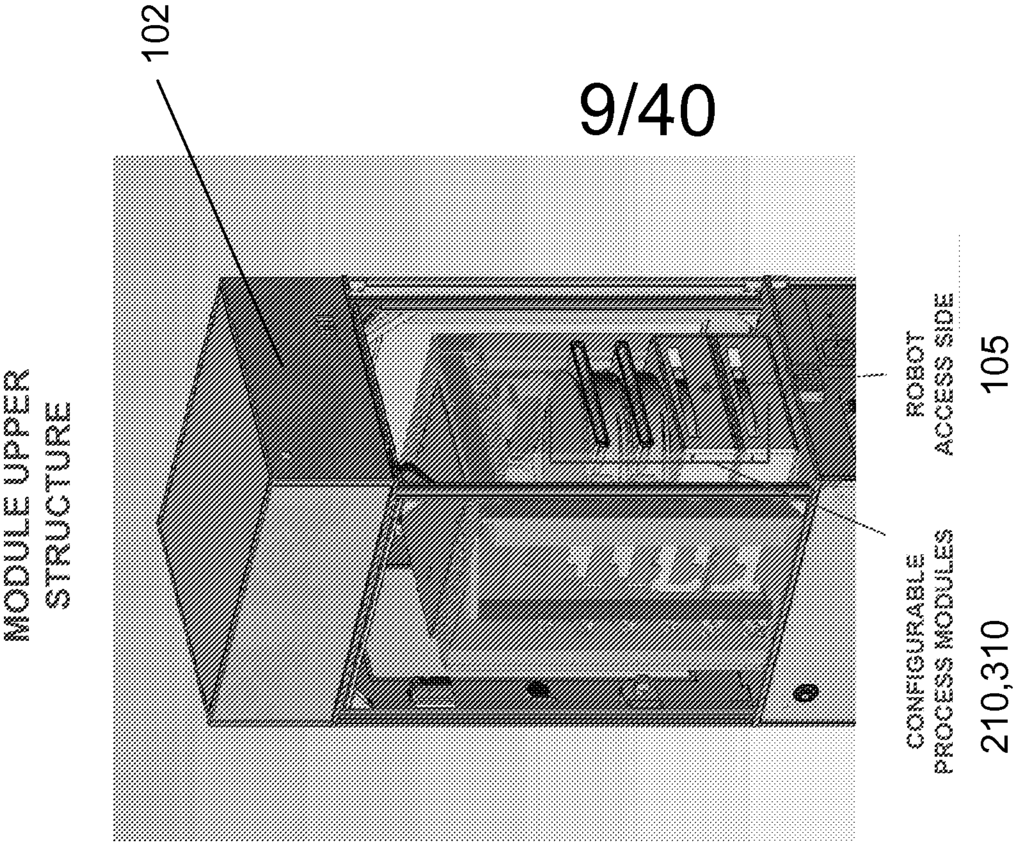

MODULE UPPER STRUCTURE
102
ROBOT ACCESS SIDE
105
CONFIGURABLE PROCESS MODULES
210,310

FIG. 6

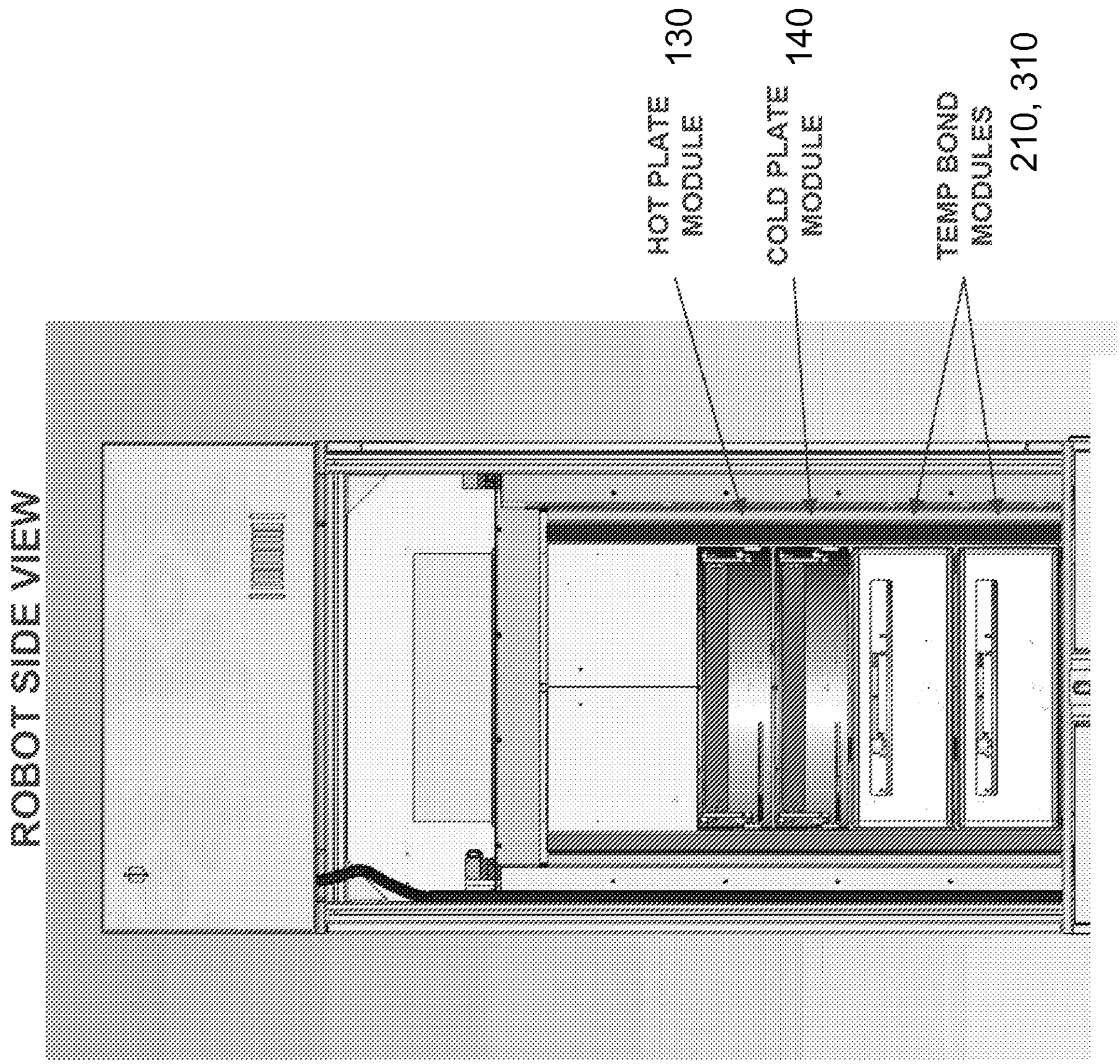

ROBOT SIDE VIEW
HOT PLATE MODULE 130
COLD PLATE MODULE 140
TEMP BOND MODULES 210, 310

FIG. 7

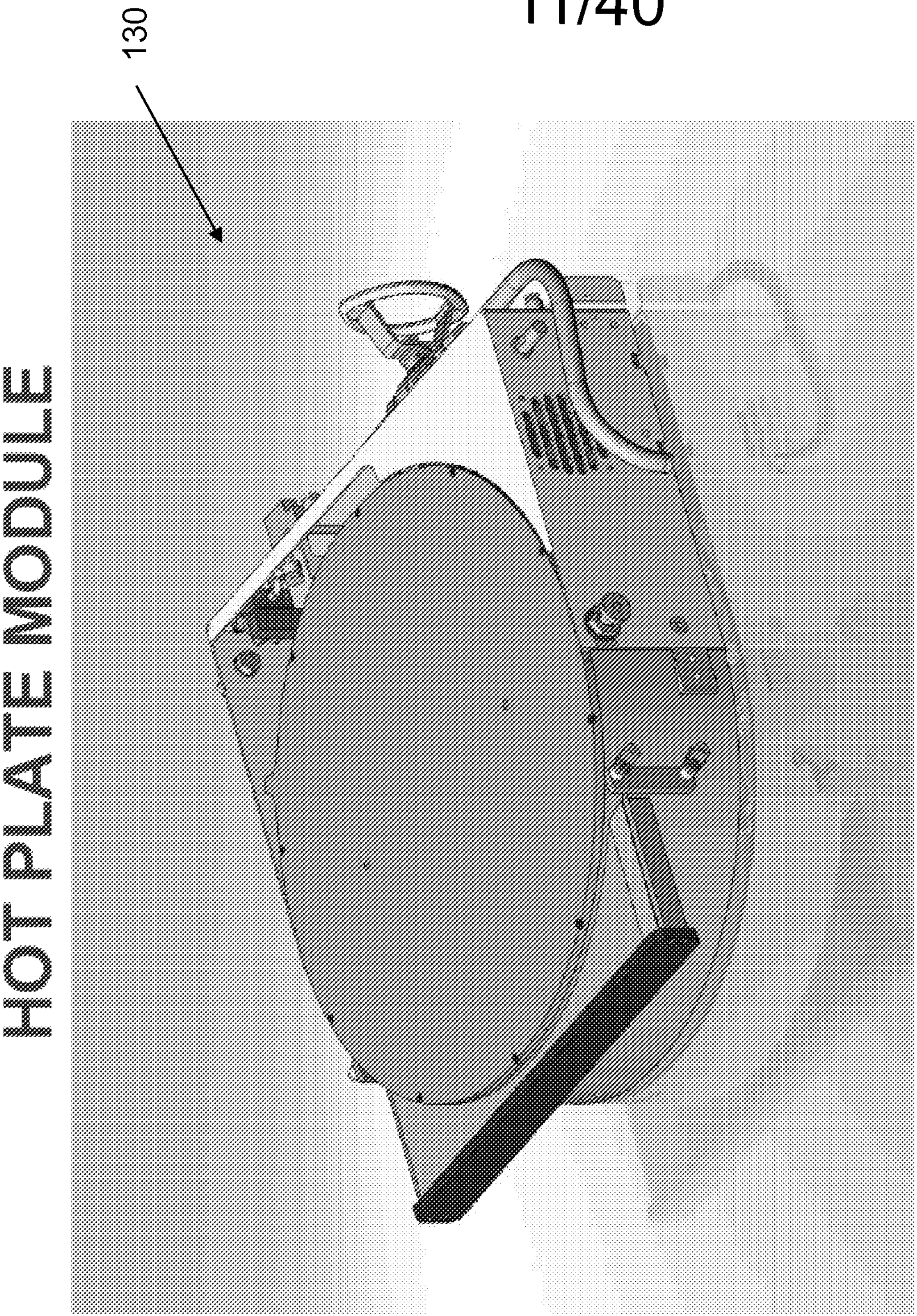


FIG. 8

TEMPORARY BOND MODULE

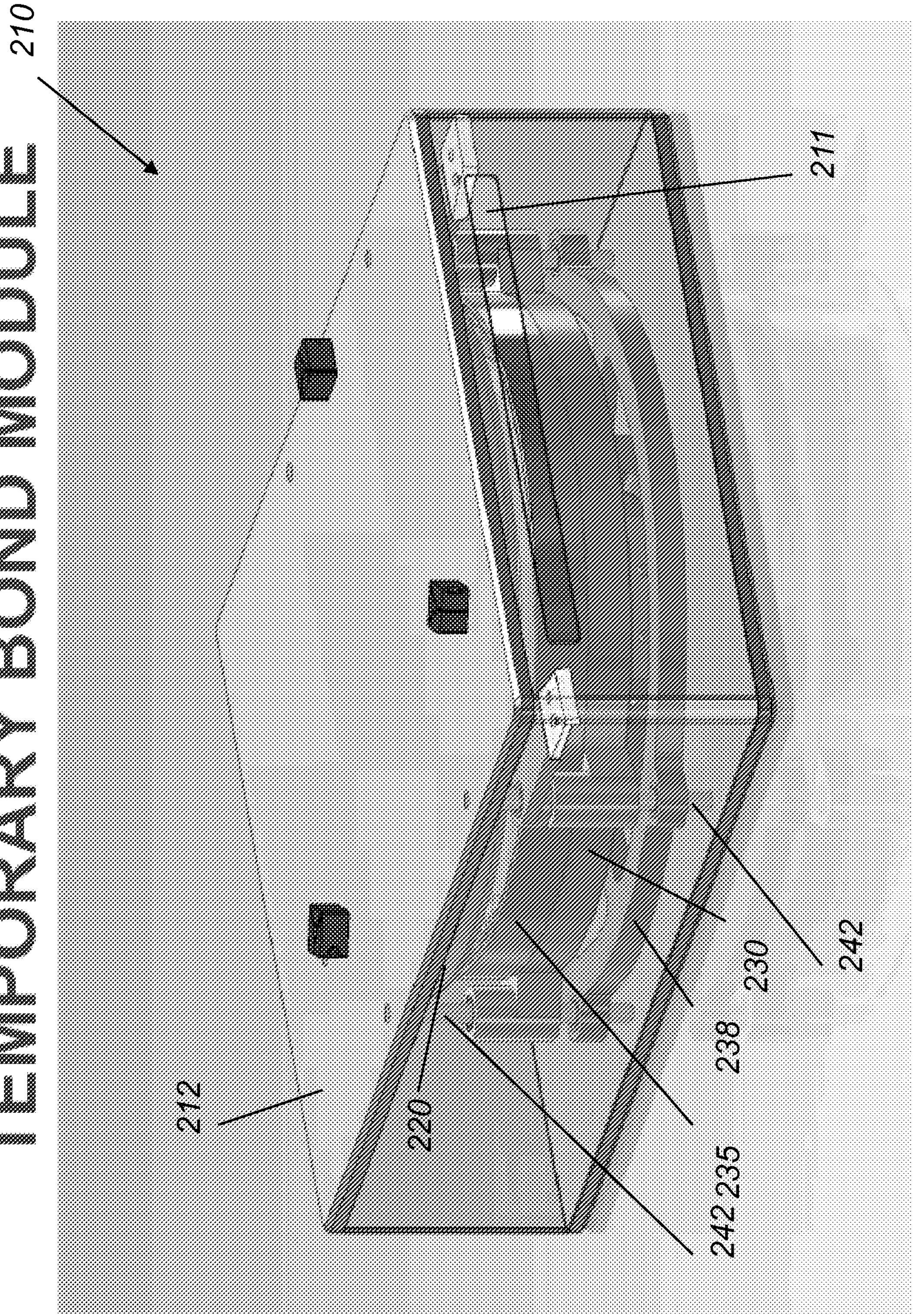


FIG. 9

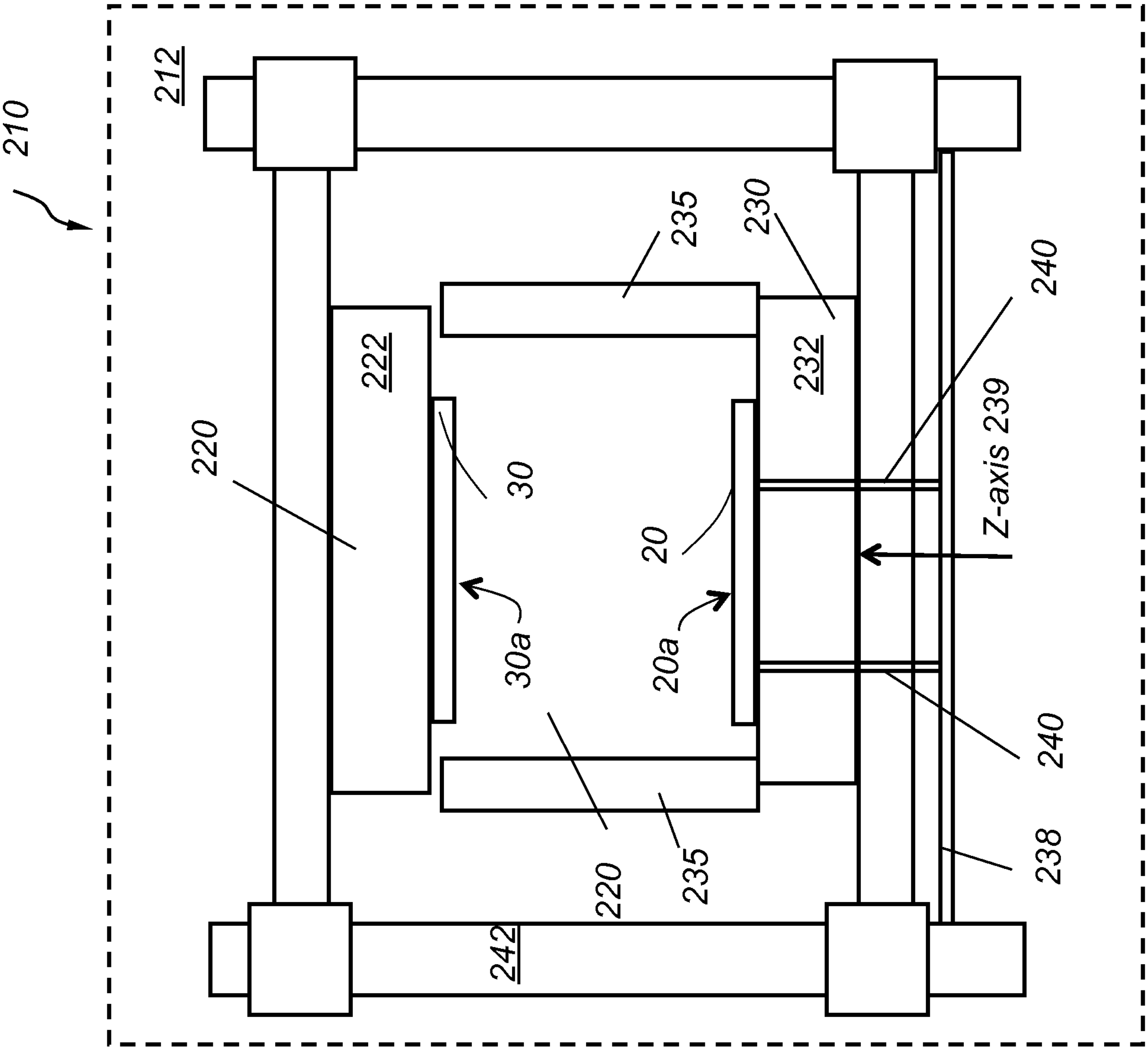

210
212
222
220
235
230
232
240
30
20
Z-axis 239
30a
20a
240
238
220
235
242

FIG. 10

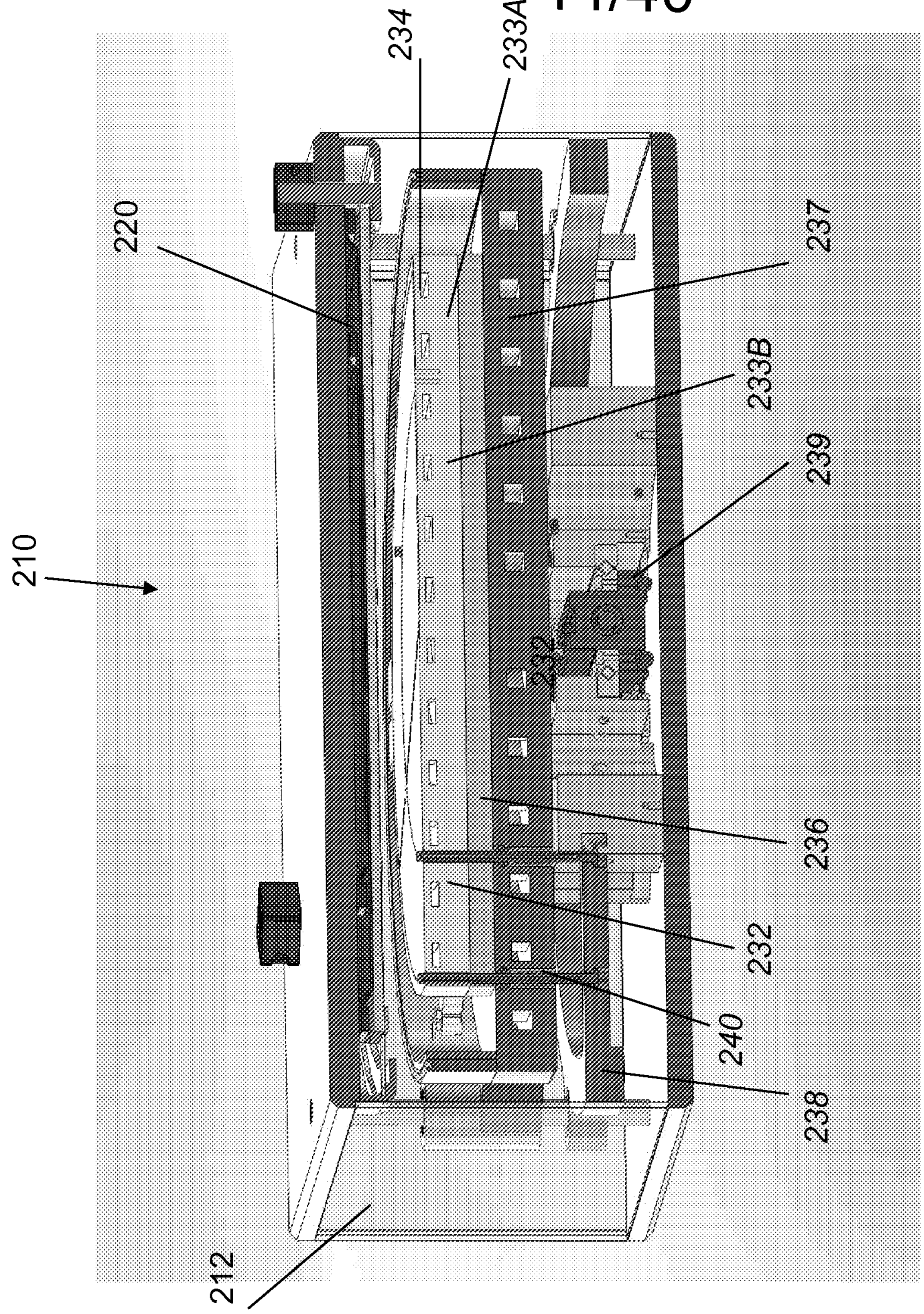


FIG. 11

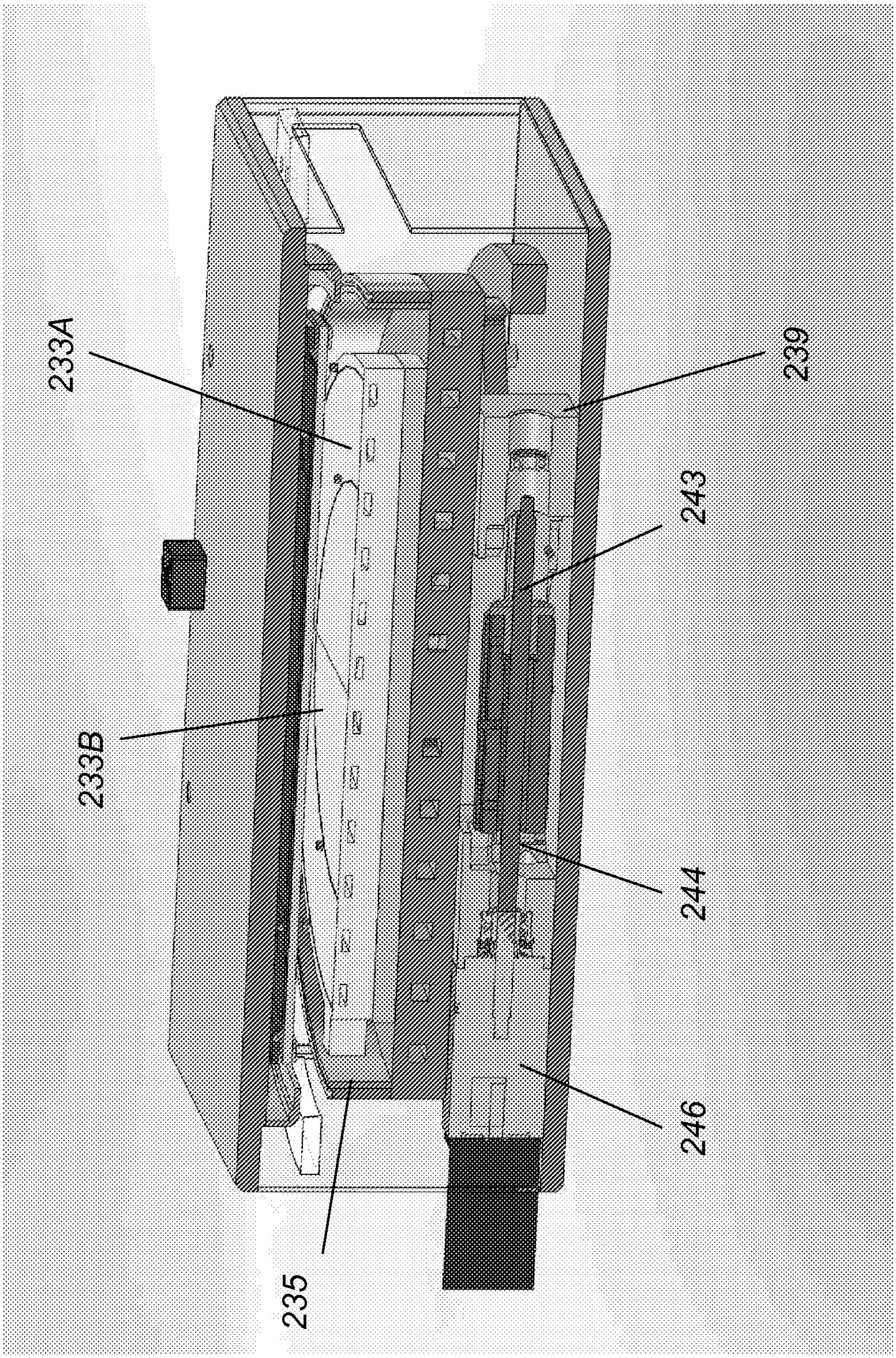


FIG. 12

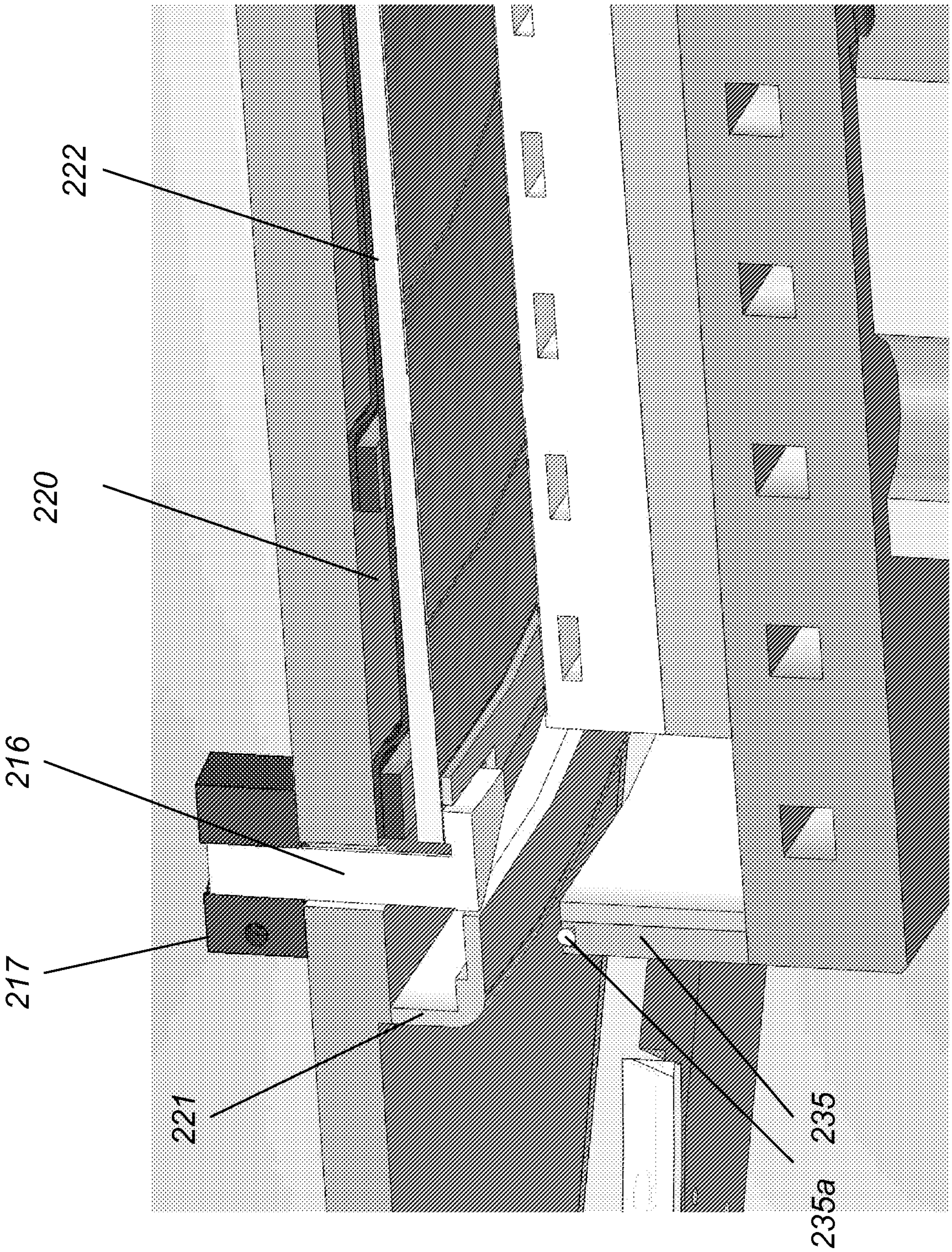


FIG. 13

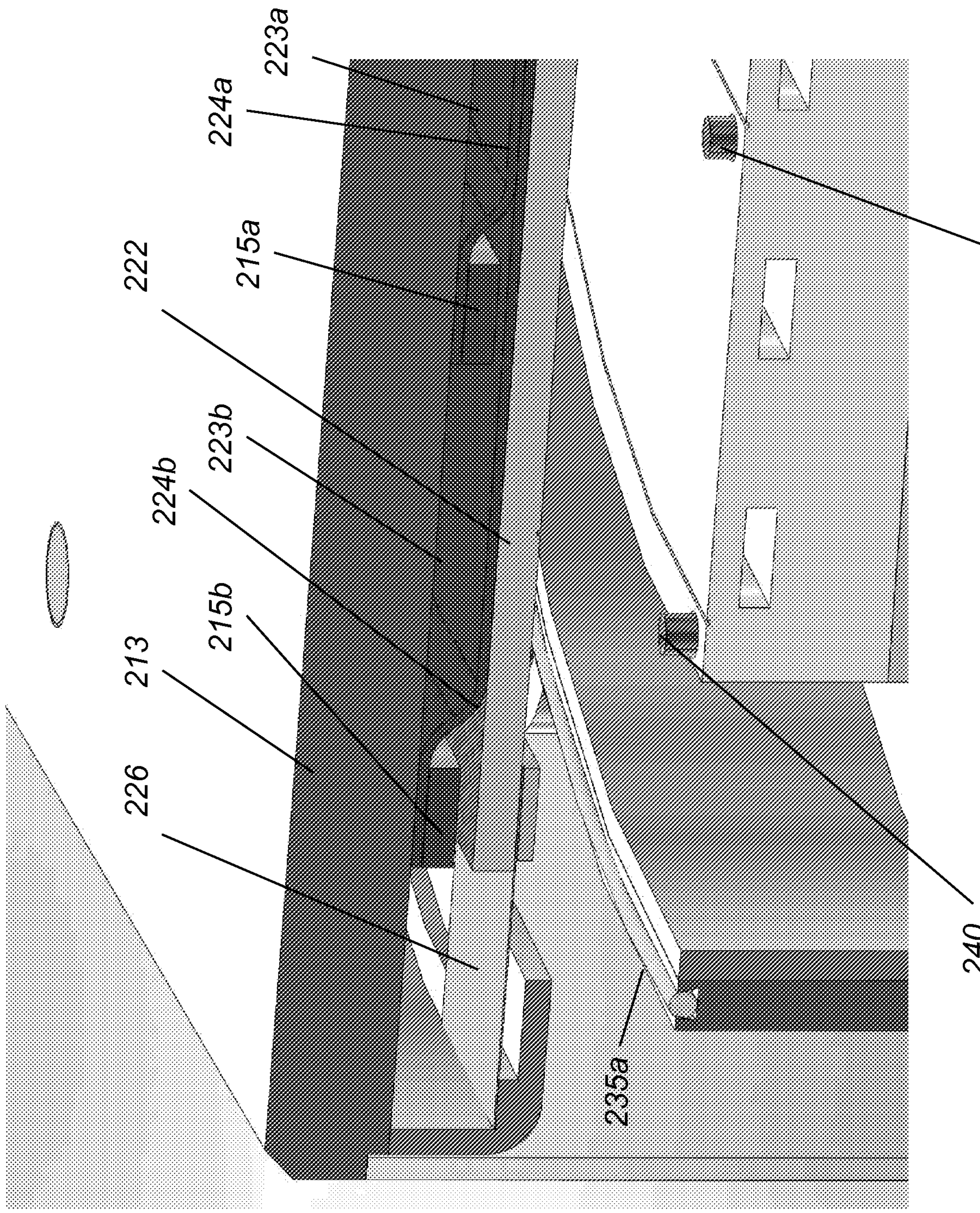


FIG. 14

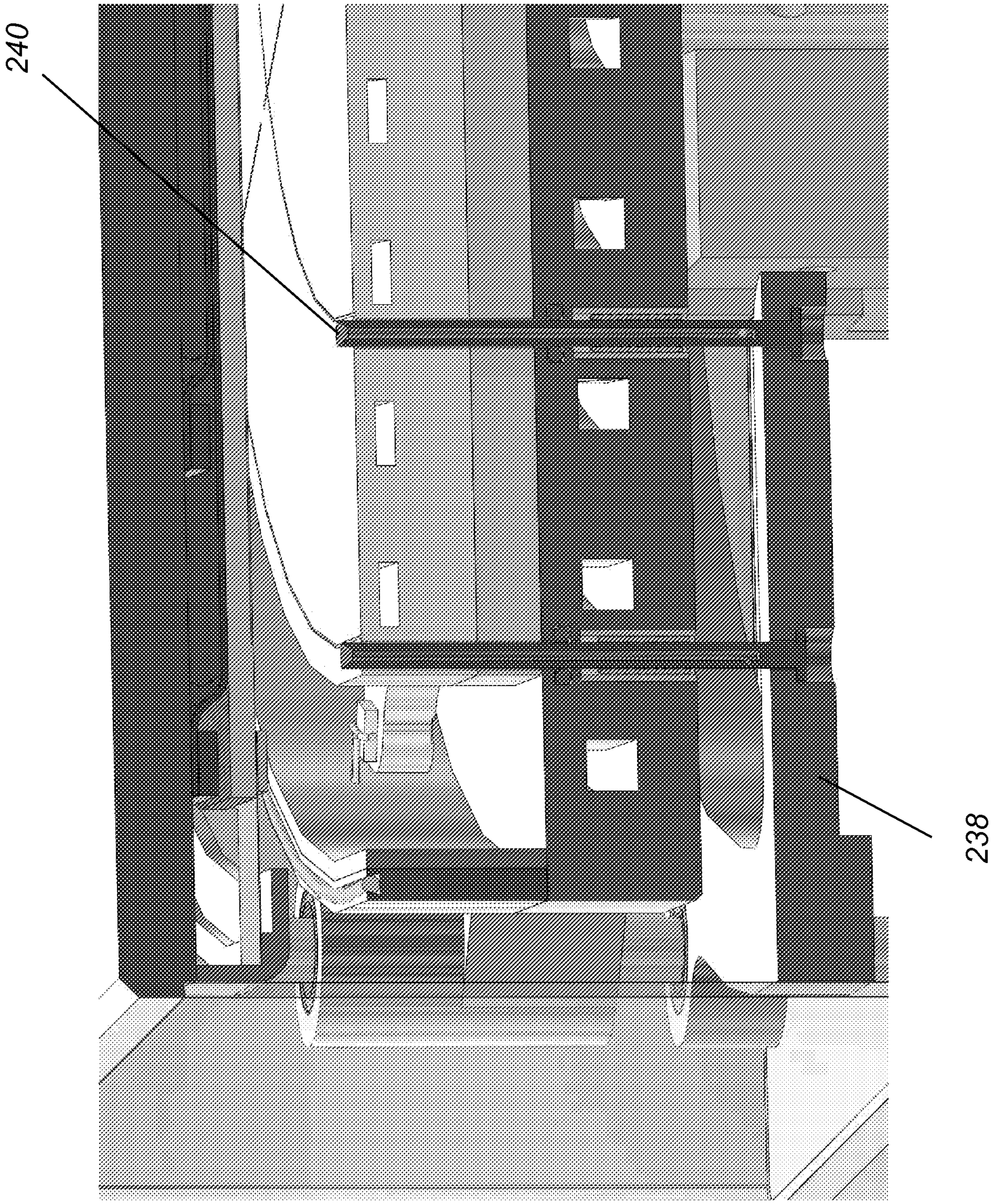


FIG. 15

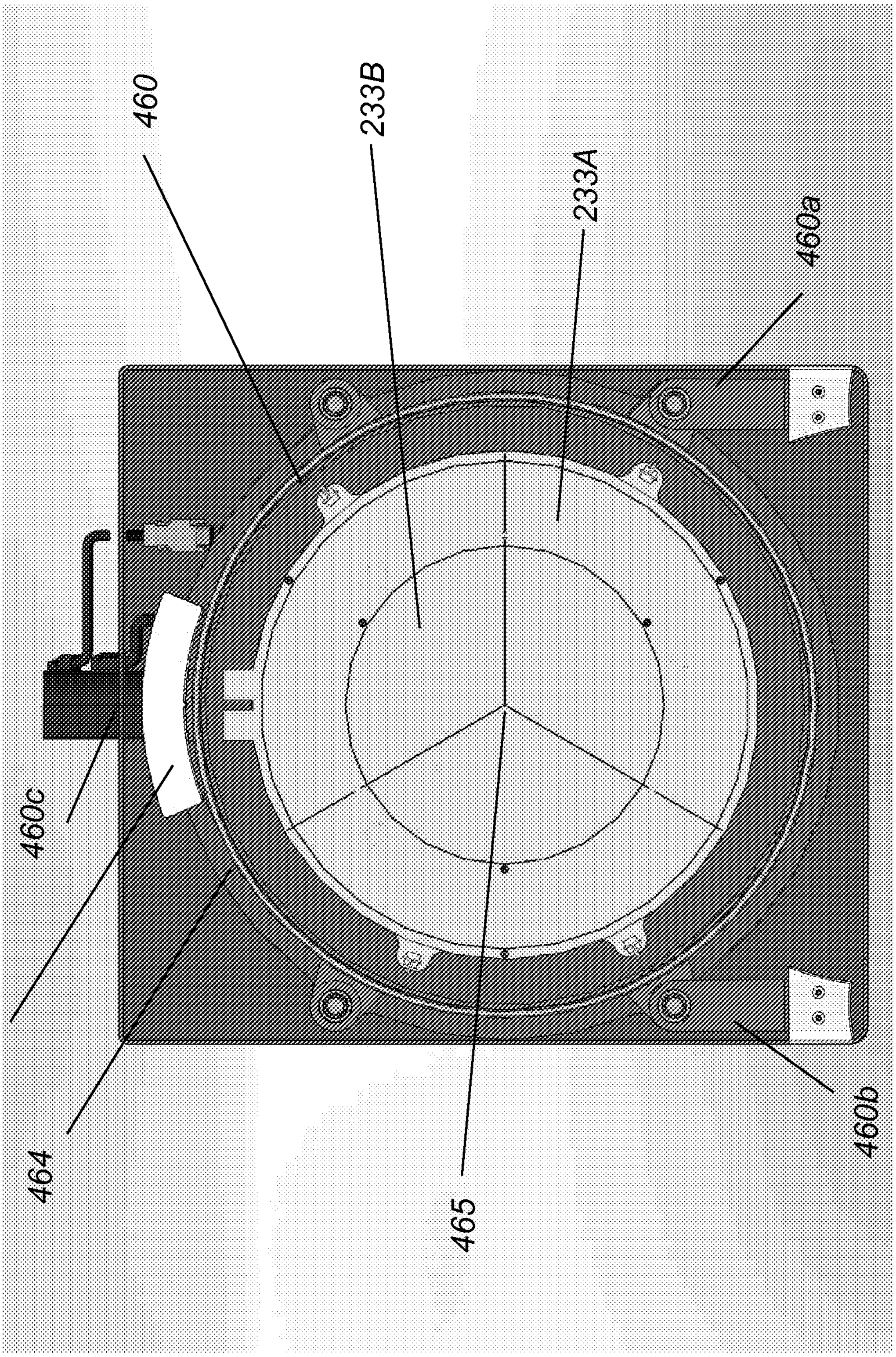


FIG. 16

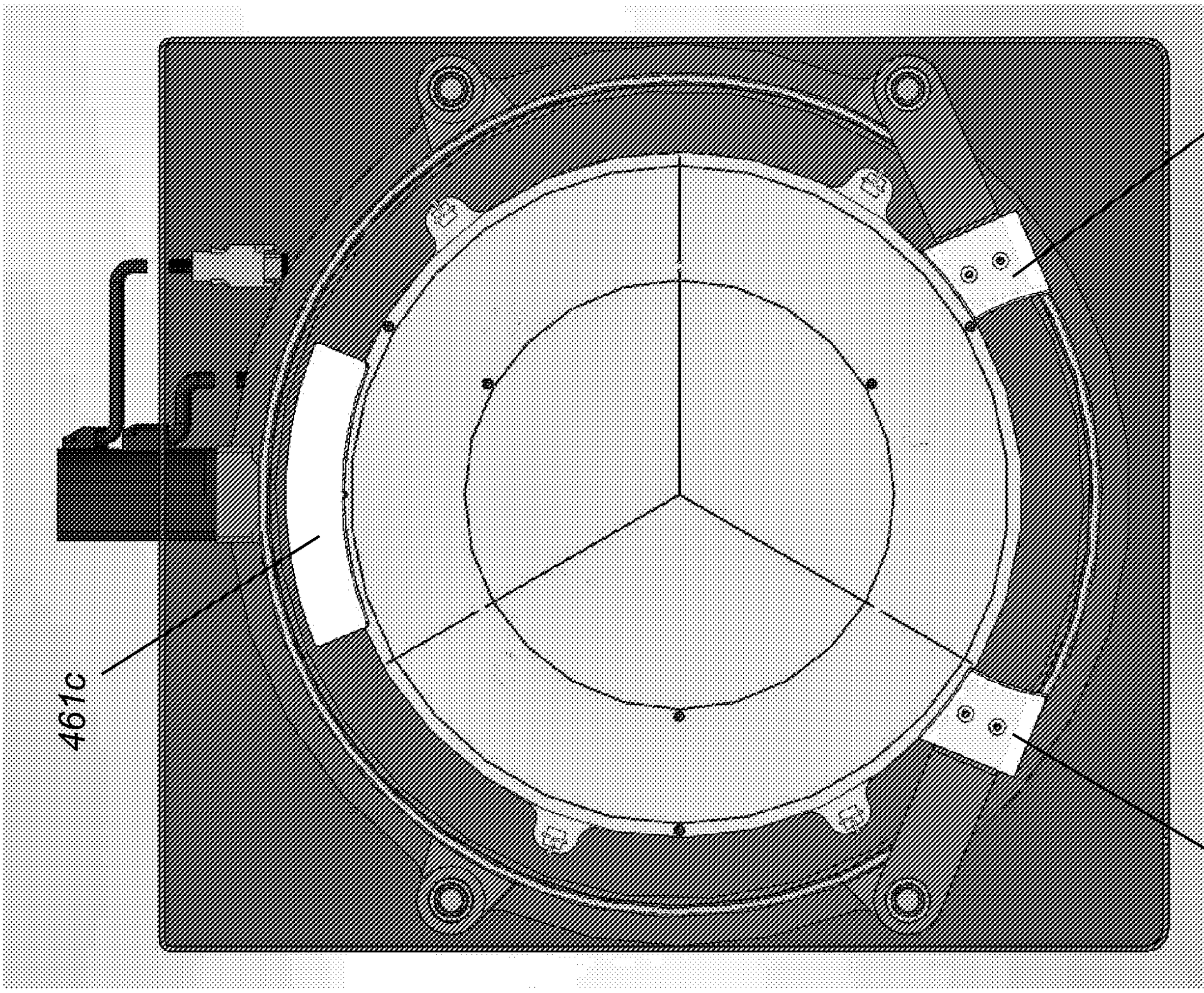


FIG. 17

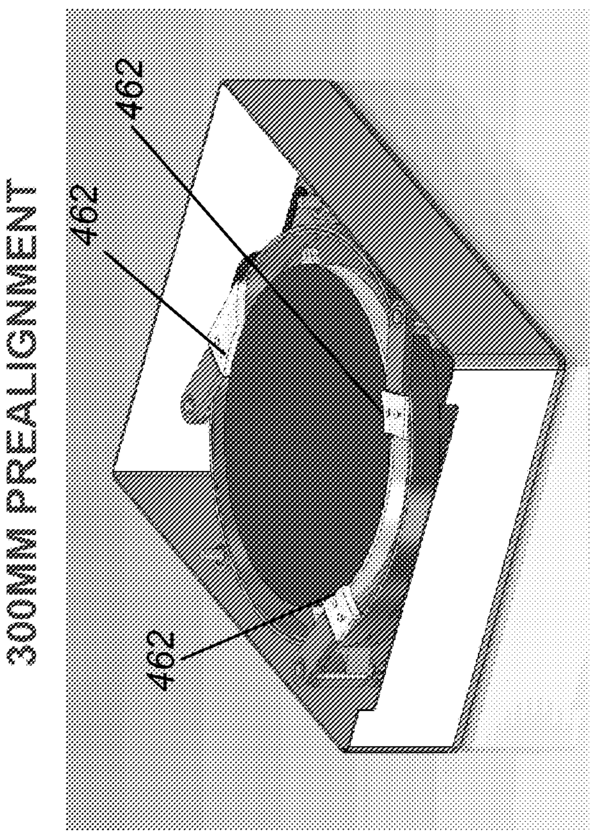


FIG. 18A

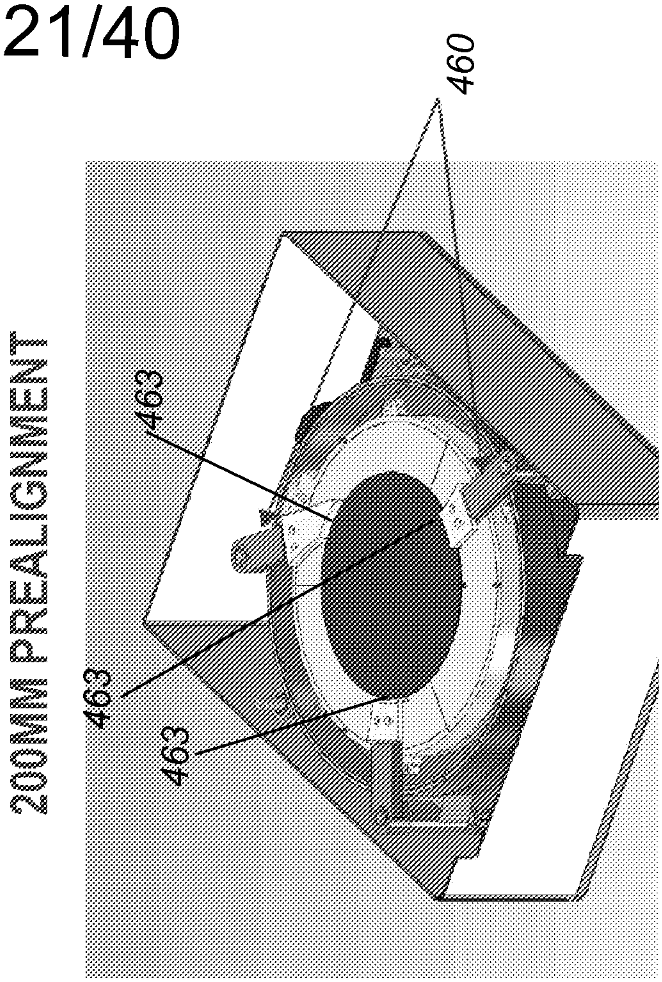


FIG. 18B

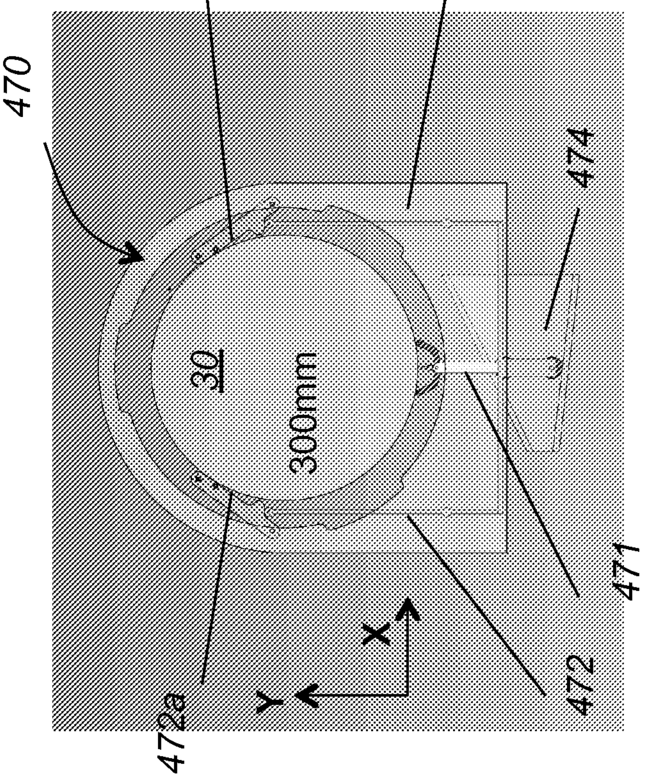


FIG. 19A

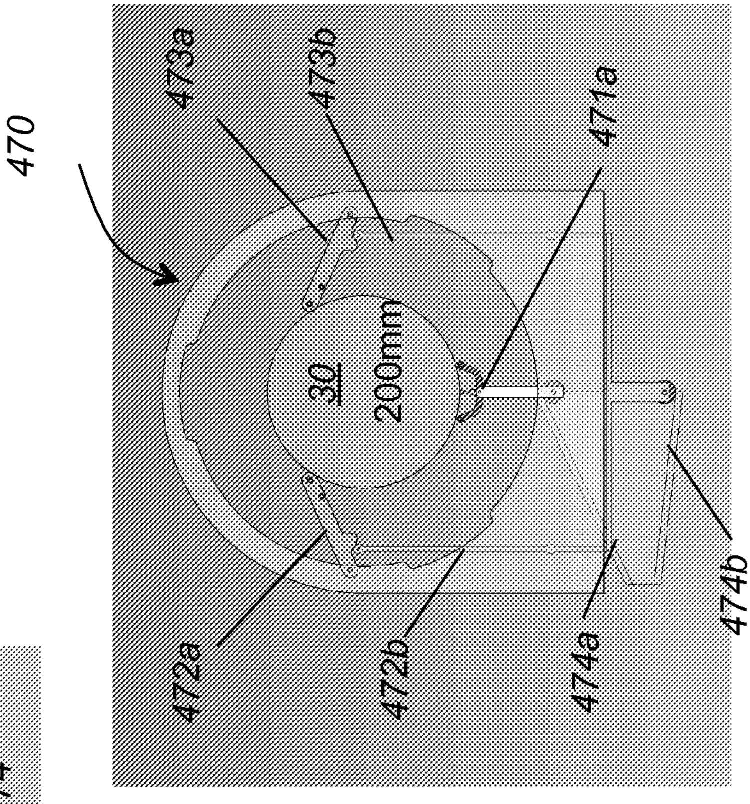


FIG. 19B

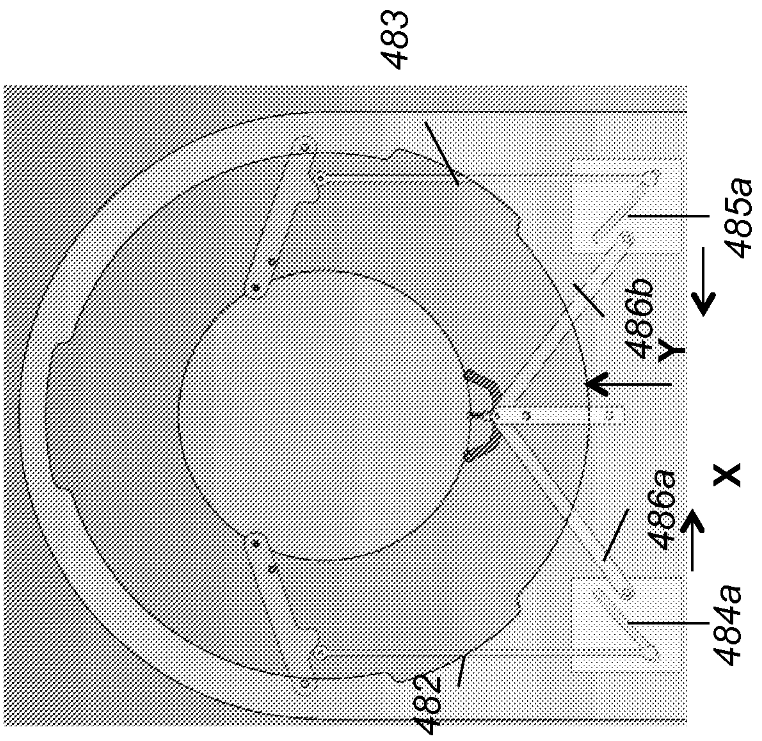


FIG. 19D

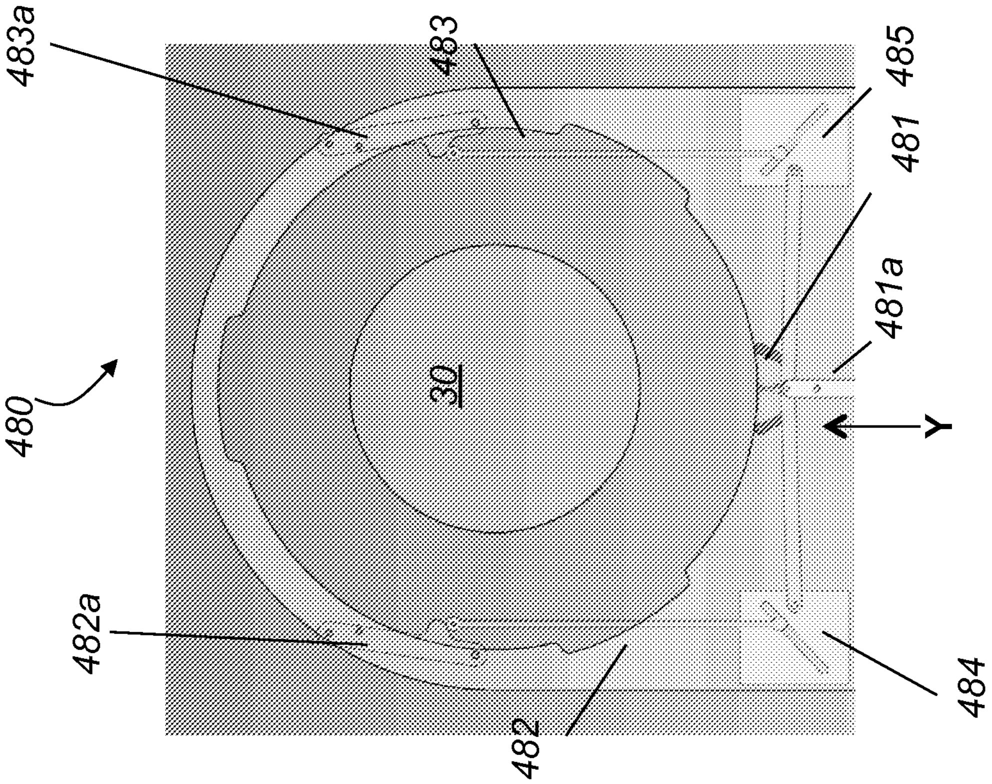


FIG. 19C

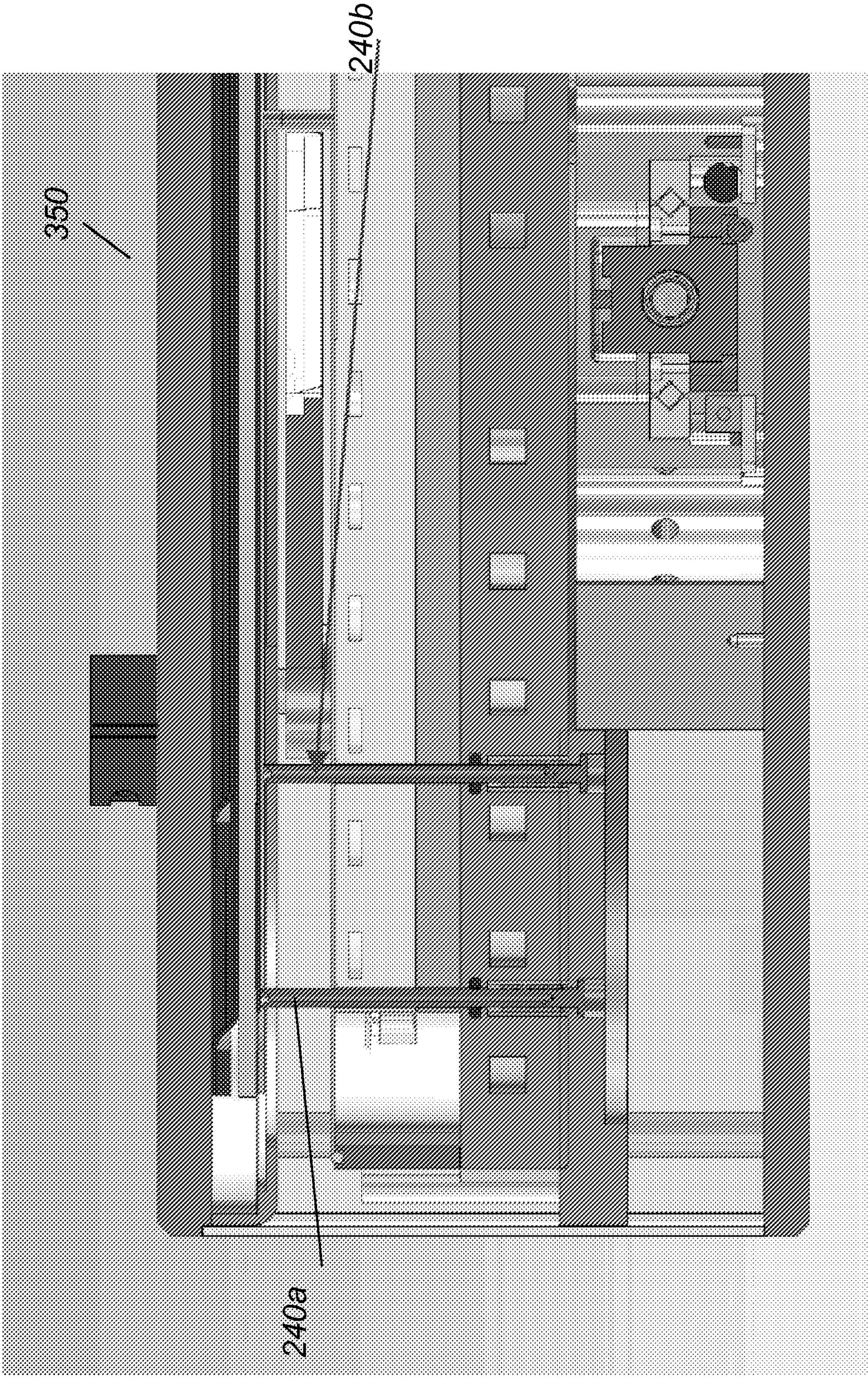


FIG. 20A

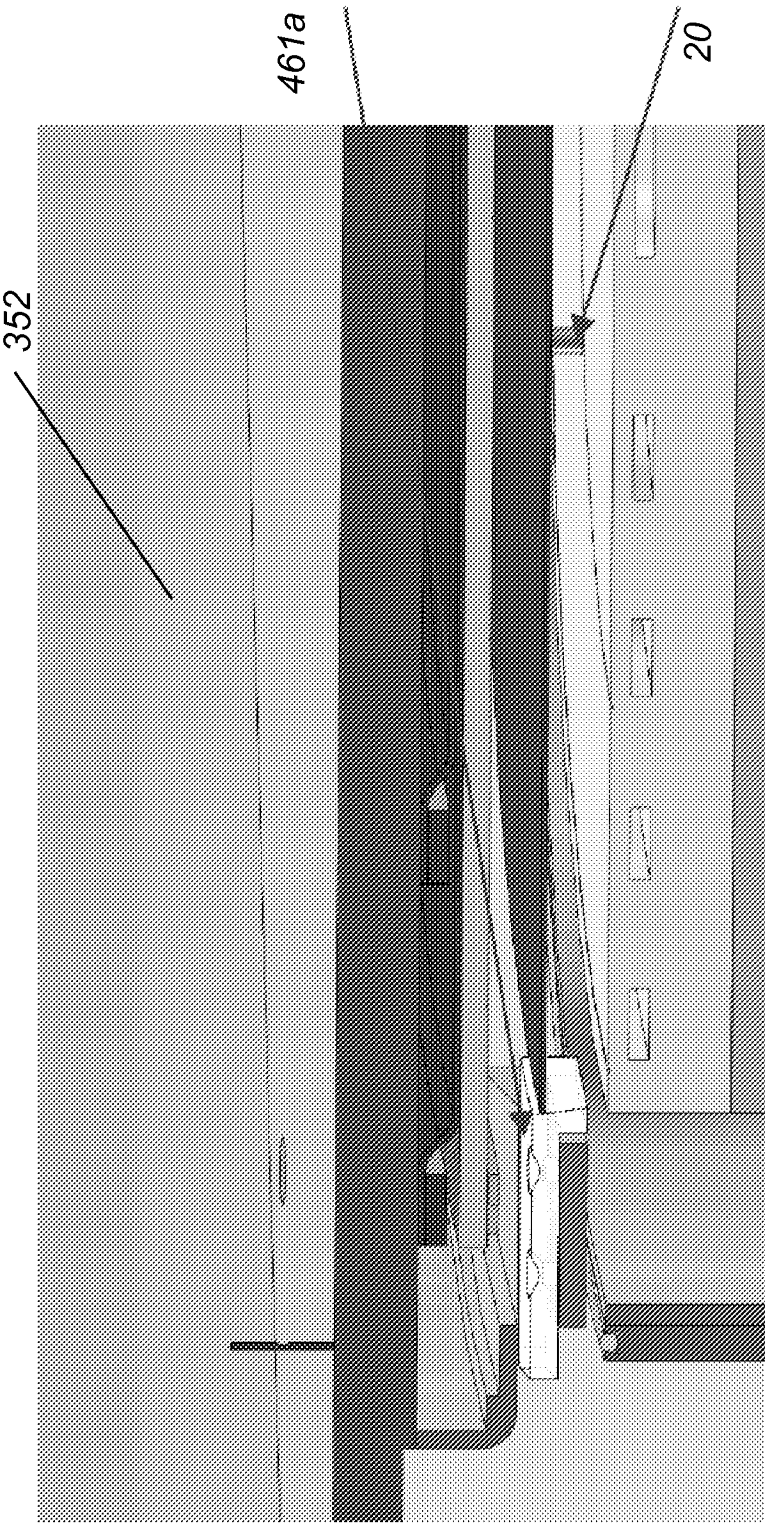


FIG. 20B

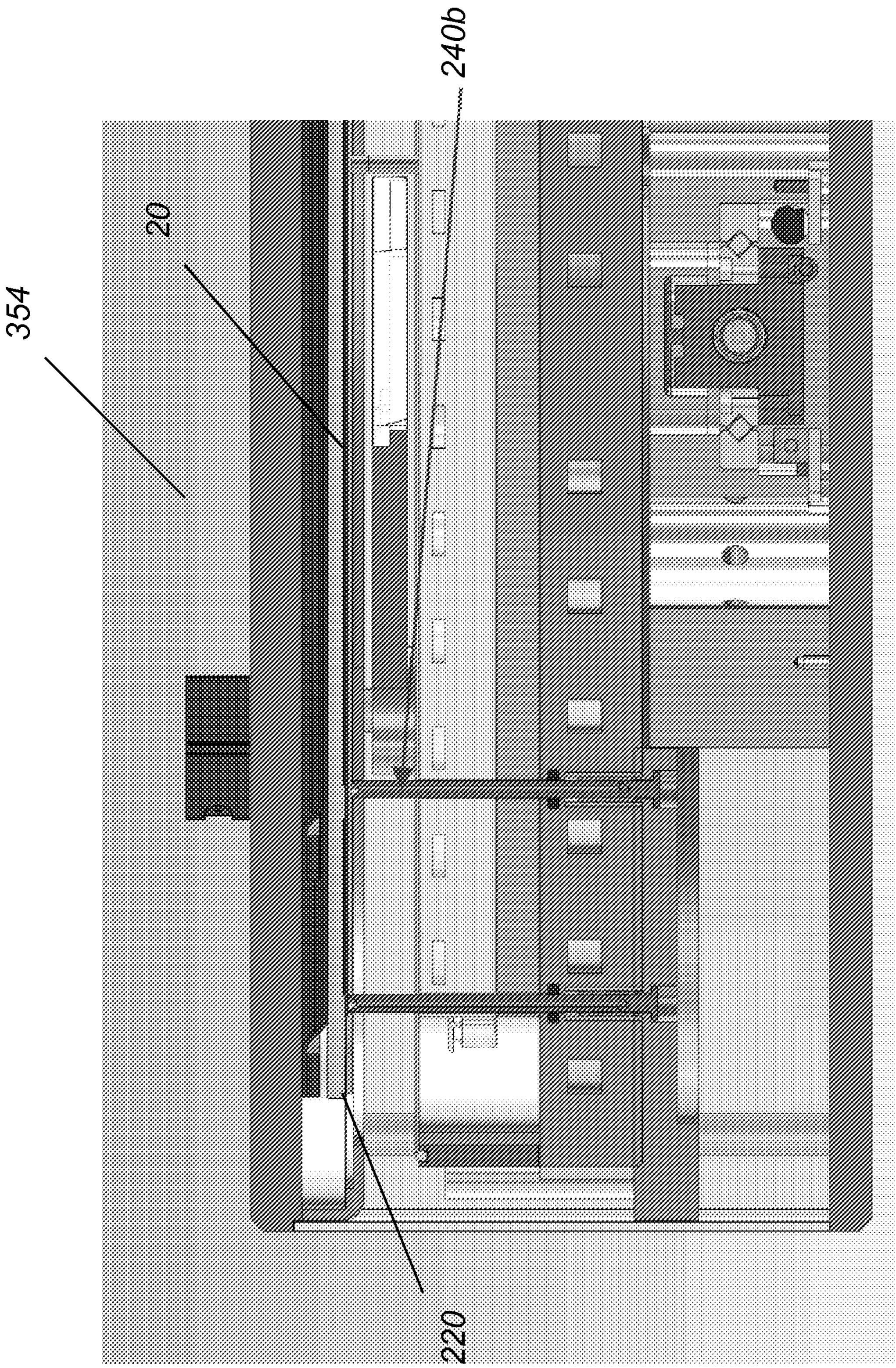


FIG. 20C

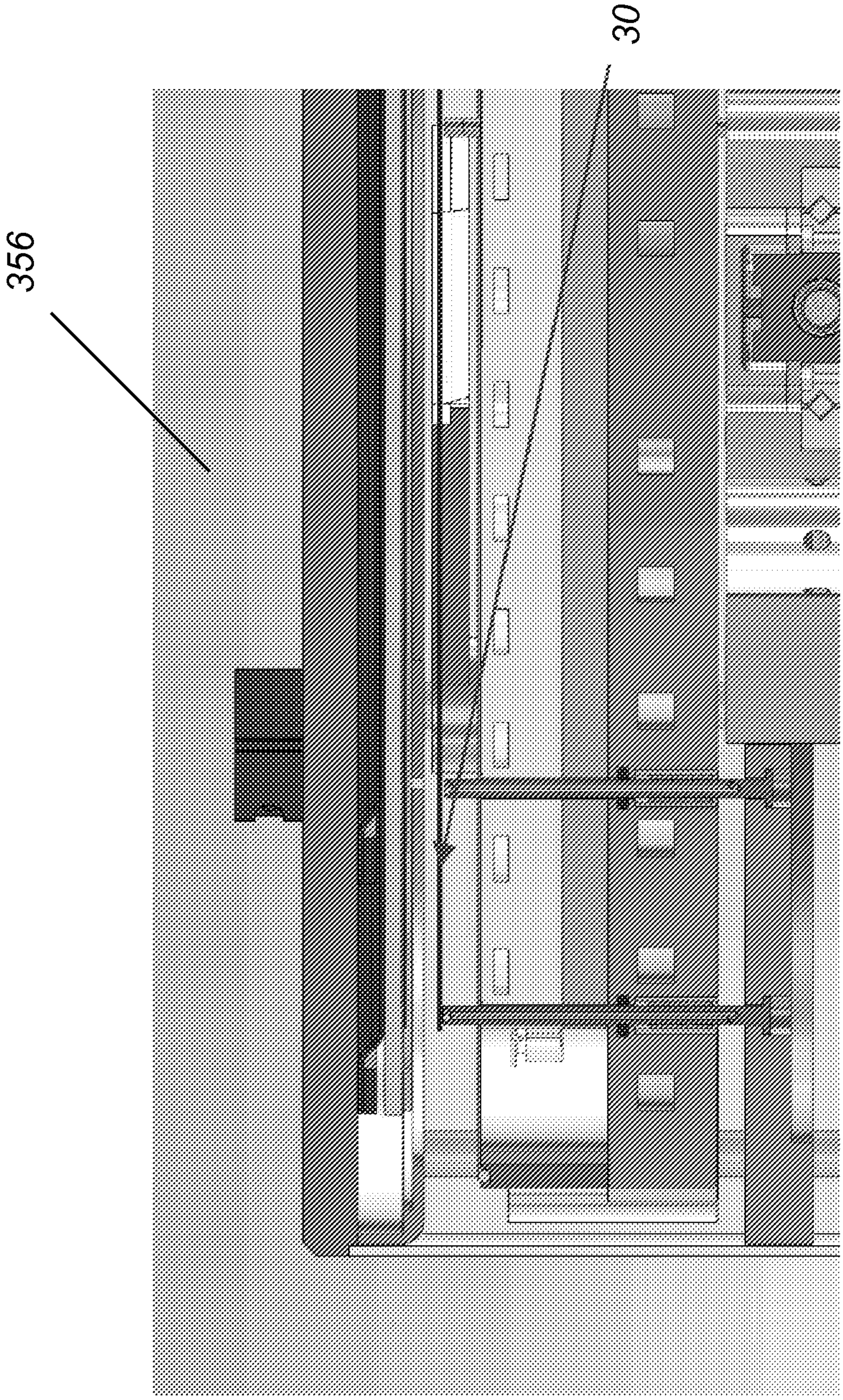


FIG. 21A

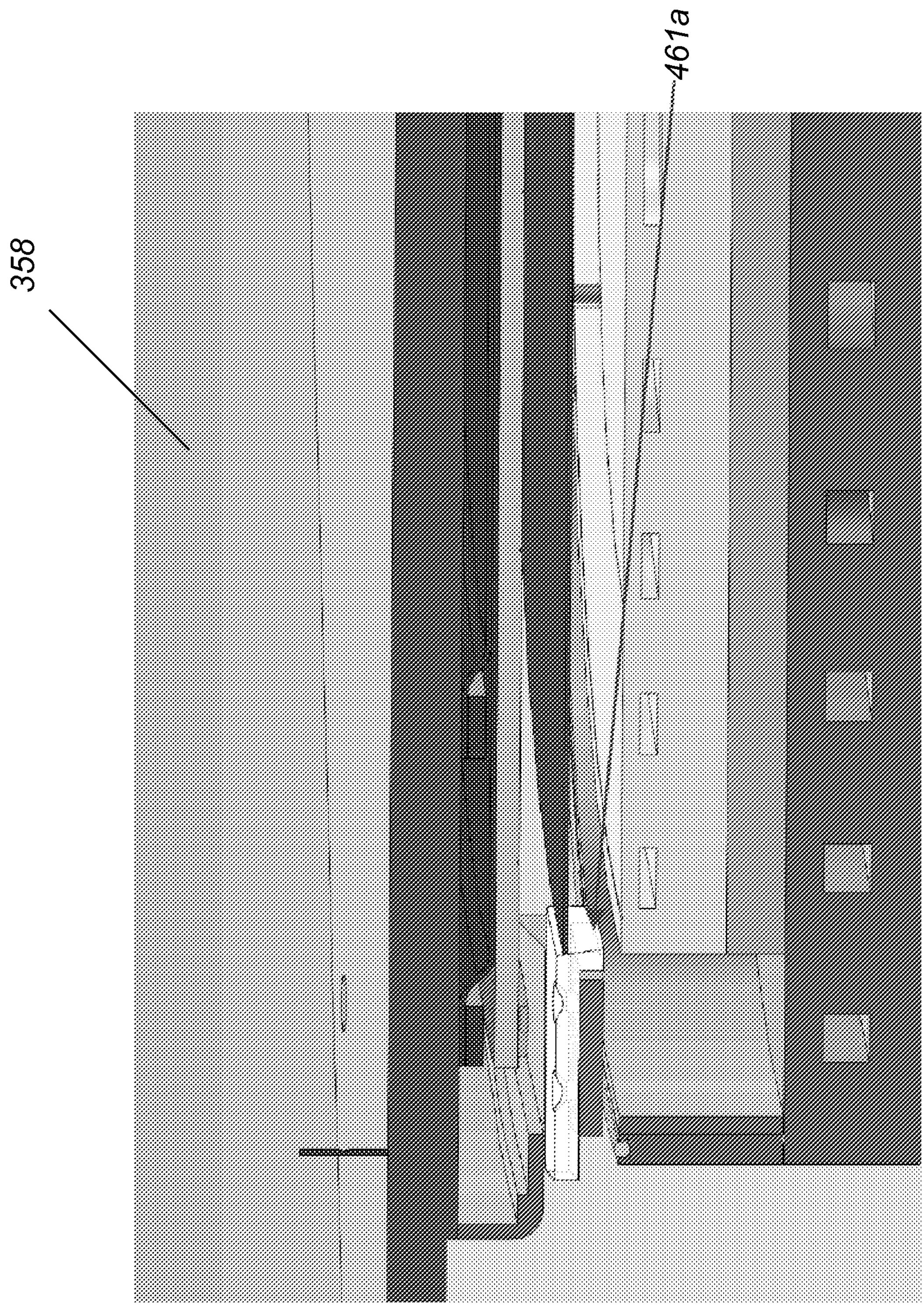


FIG. 21B

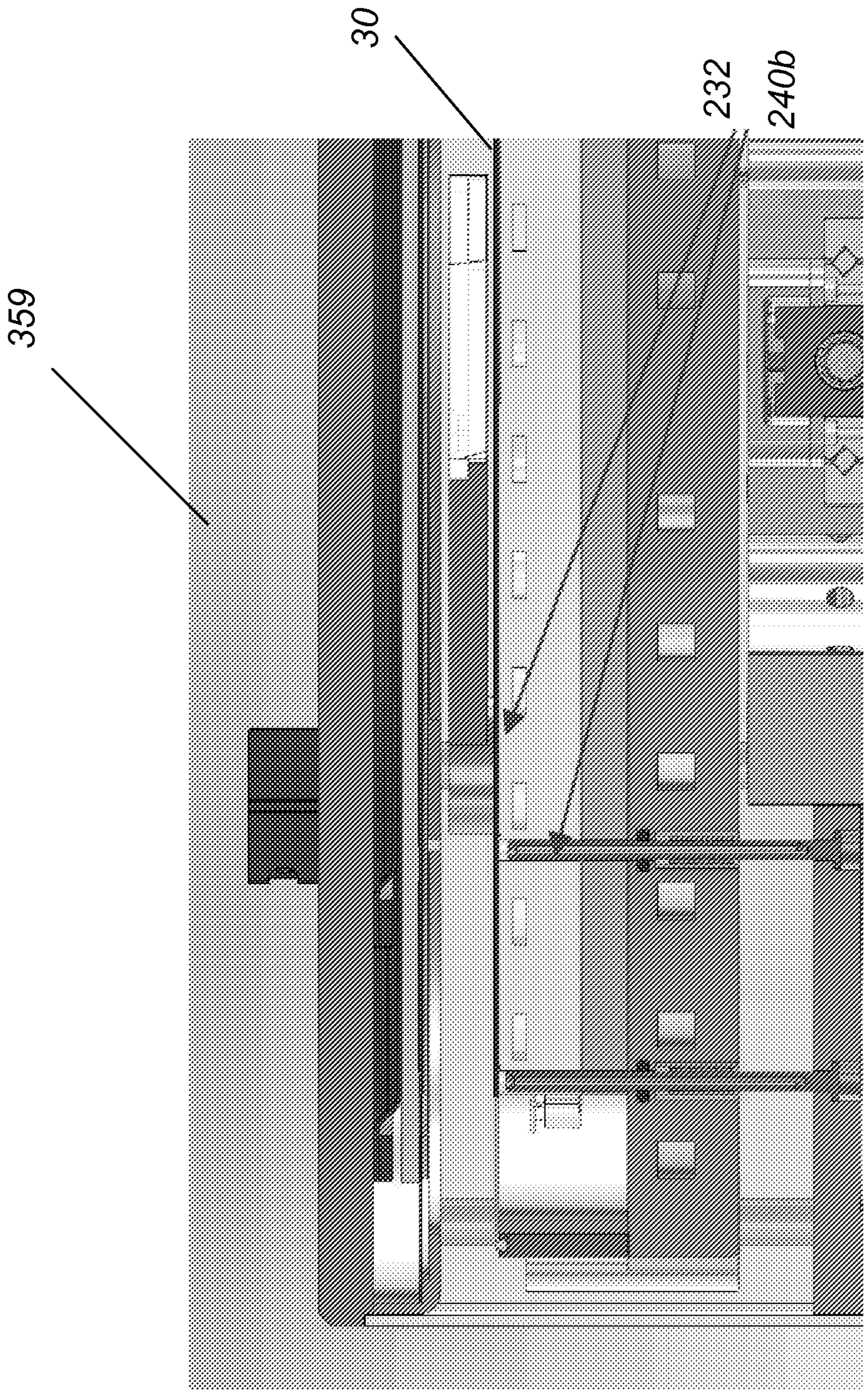


FIG. 21C

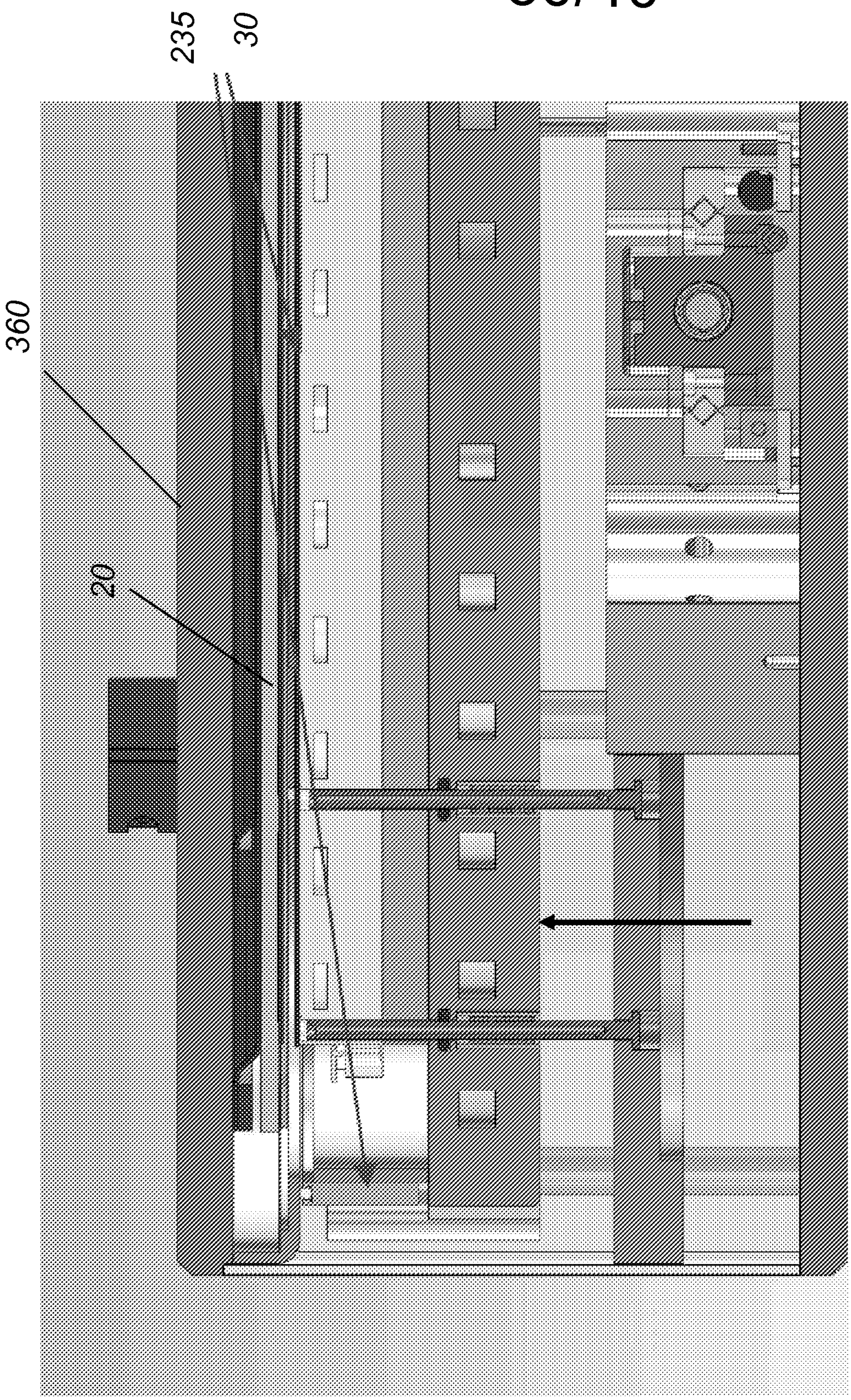


FIG. 22A

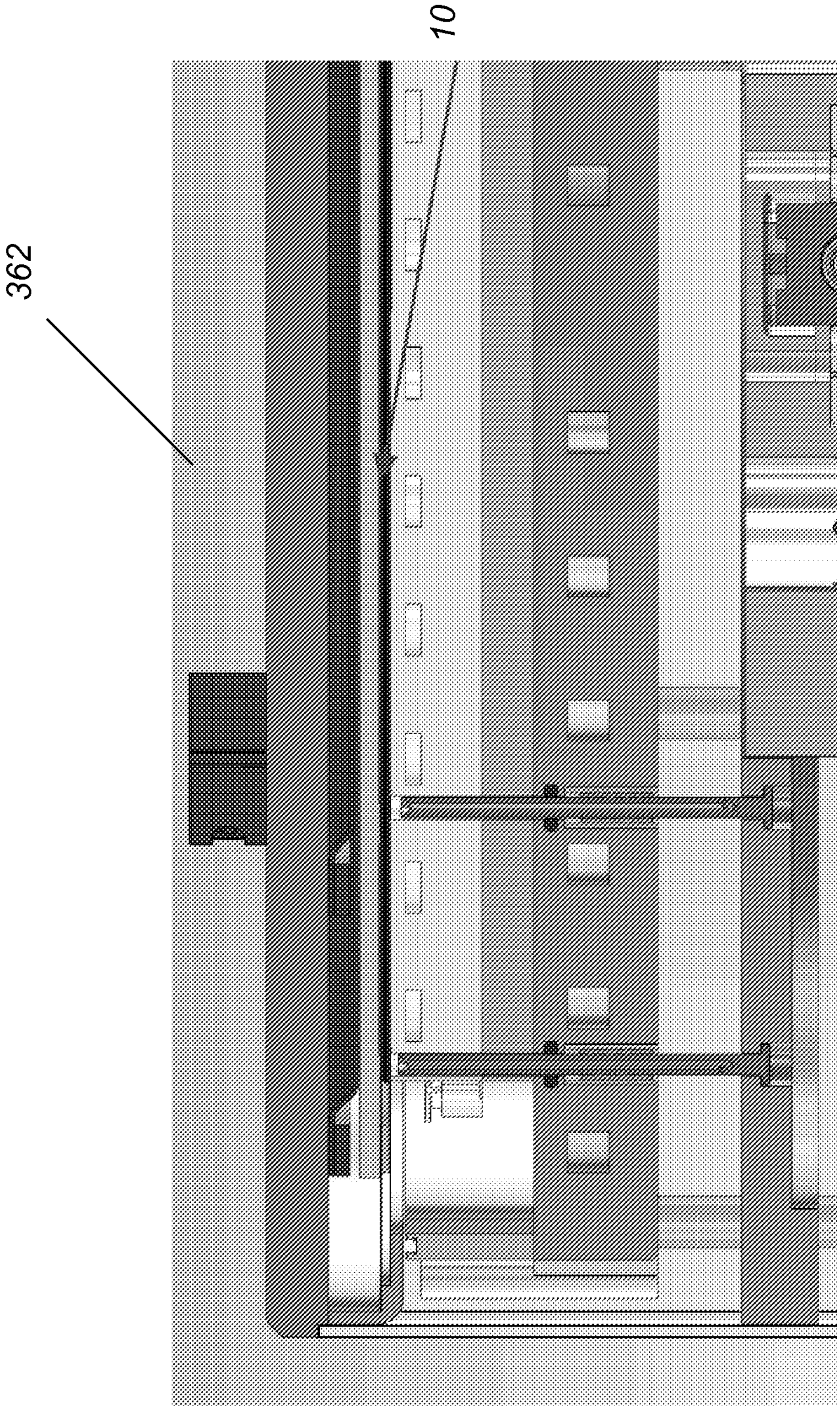


FIG. 22B

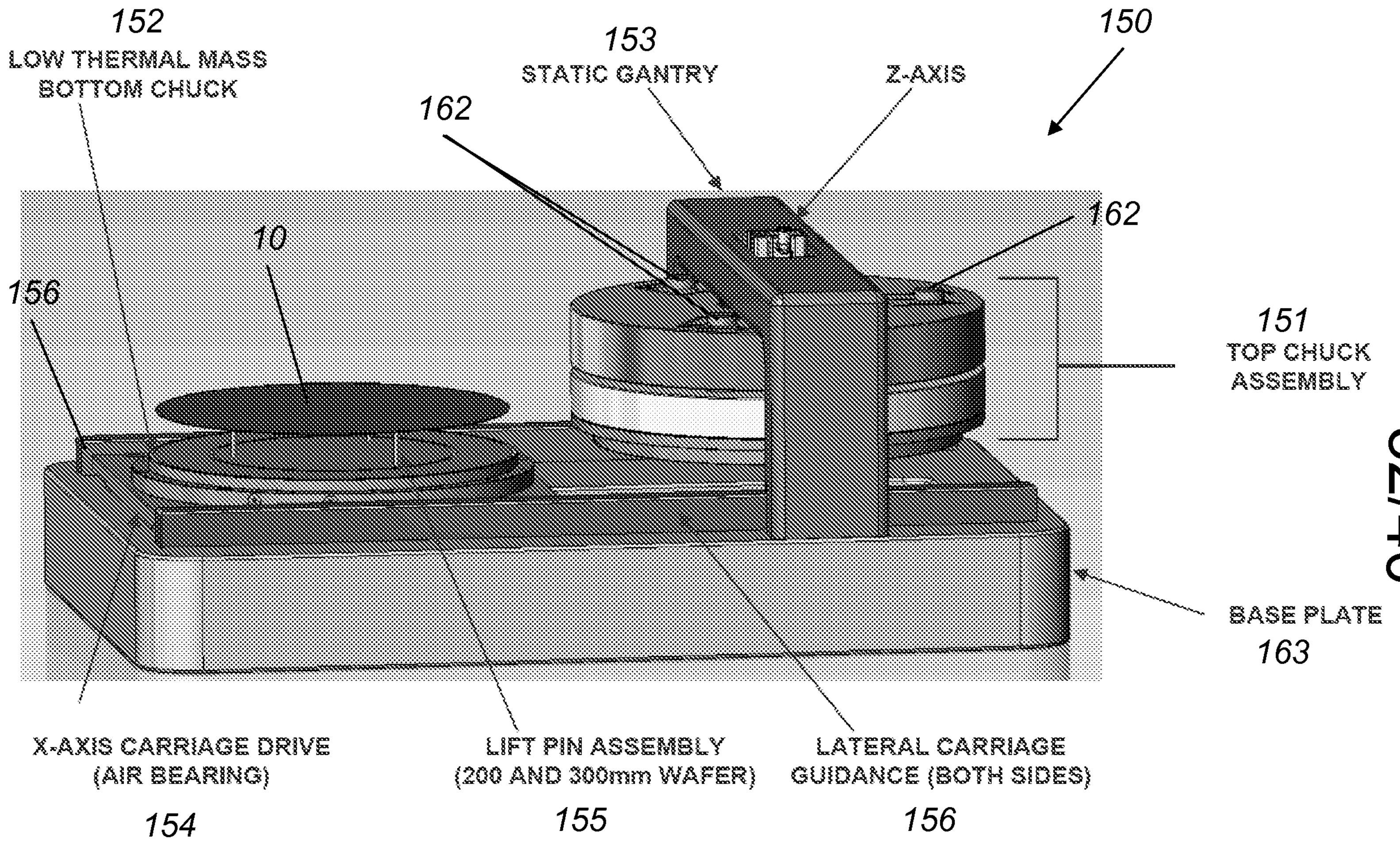

150
152
LOW THERMAL MASS
BOTTOM CHUCK
153
STATIC GANTRY
Z-AXIS
162
162
10
156
151
TOP CHUCK
ASSEMBLY
BASE PLATE
163
X-AXIS CARRIAGE DRIVE
(AIR BEARING)
154
LIFT PIN ASSEMBLY
(200 AND 300mm WAFER)
155
LATERAL CARRIAGE
GUIDANCE (BOTH SIDES)
156

FIG. 23

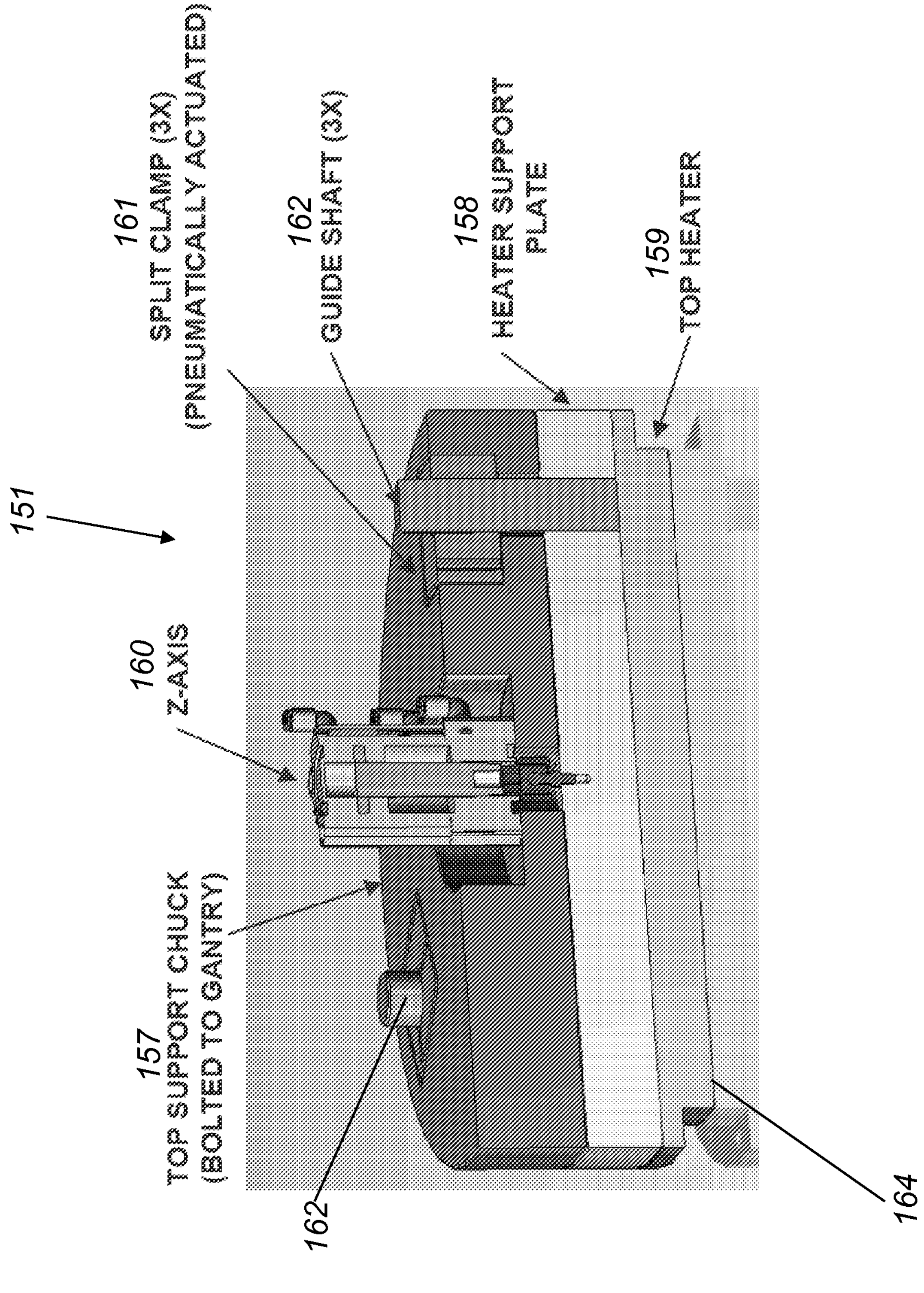

161
SPLIT CLAMP (3X)
(PNEUMATICALLY ACTUATED)
162
GUIDE SHAFT (3X)
158
HEATER SUPPORT
PLATE
159
TOP HEATER
151
160
Z-AXIS
157
TOP SUPPORT CHUCK
(BOLTED TO GANTRY)
162
164

FIG. 24

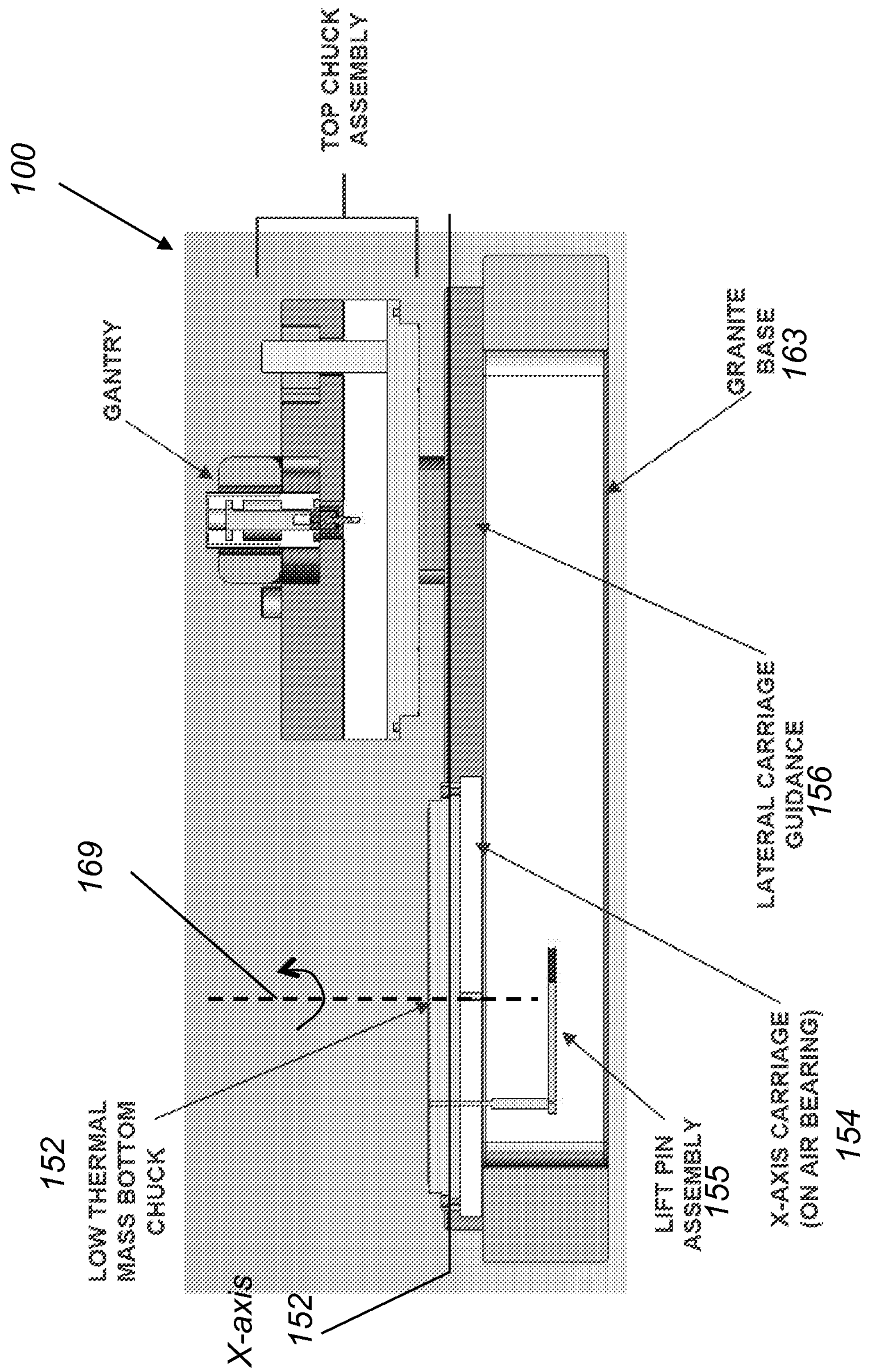

100
TOP CHUCK ASSEMBLY
GANTRY
GRANITE BASE
163
LATERAL CARRIAGE GUIDANCE
156
169
X-AXIS CARRIAGE (ON AIR BEARING)
154
LIFT PIN ASSEMBLY
155
152
LOW THERMAL MASS BOTTOM CHUCK
X-axis
152

FIG. 25

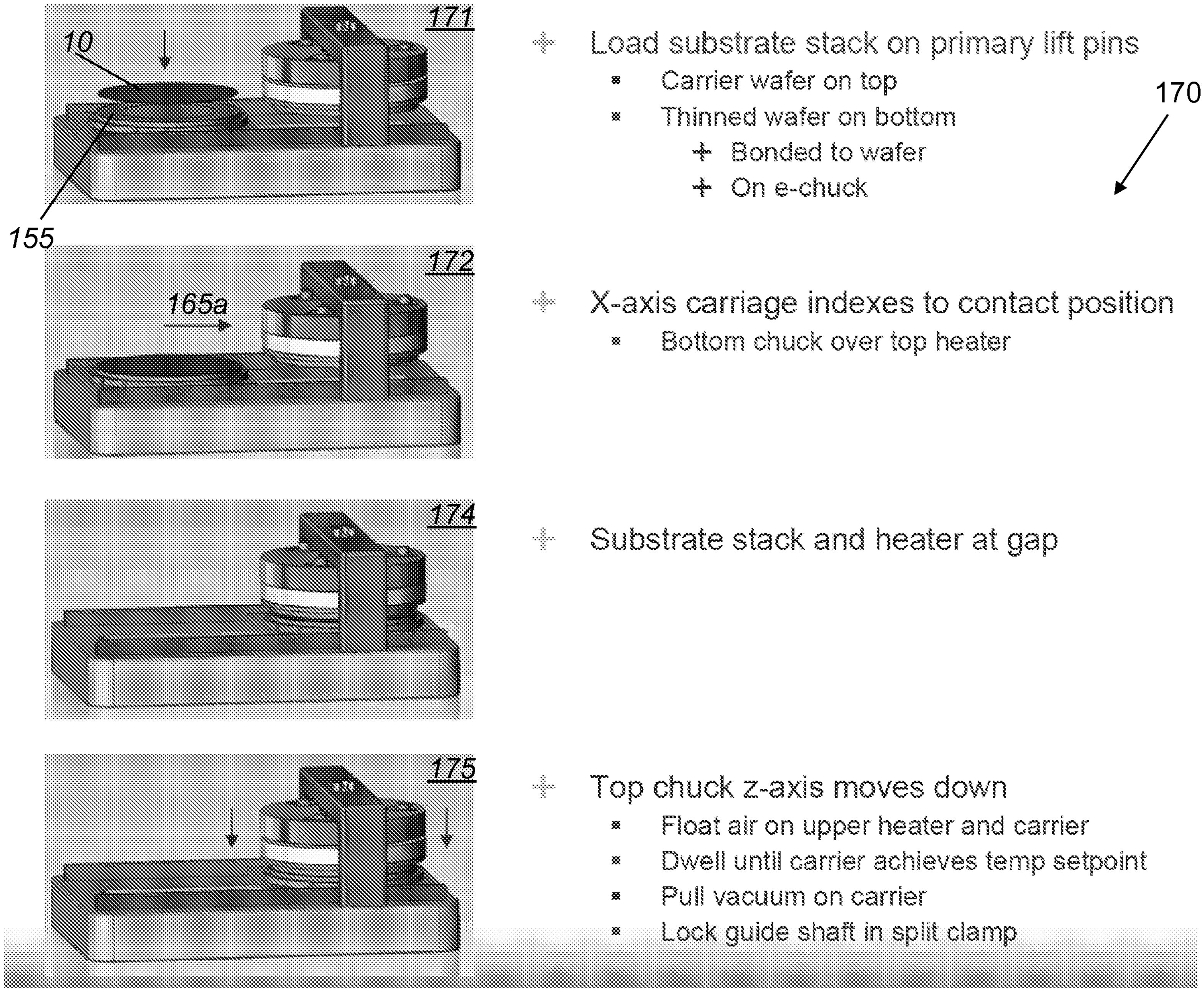
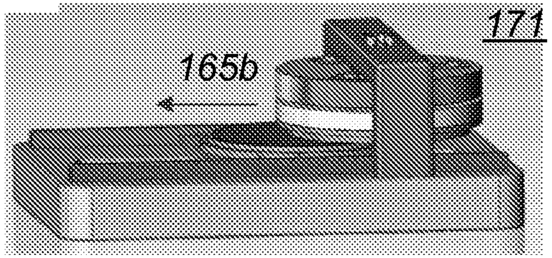
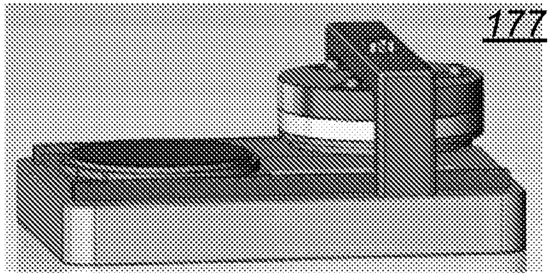

10
155
171
172
165a
174
175
170
Load substrate stack on primary lift pins
Carrier wafer on top
Thinned wafer on bottom
Bonded to wafer
On e-chuck
X-axis carriage indexes to contact position
Bottom chuck over top heater
Substrate stack and heater at gap
Top chuck z-axis moves down
Float air on upper heater and carrier
Dwell until carrier achieves temp setpoint
Pull vacuum on carrier
Lock guide shaft in split clamp

FIG. 26A

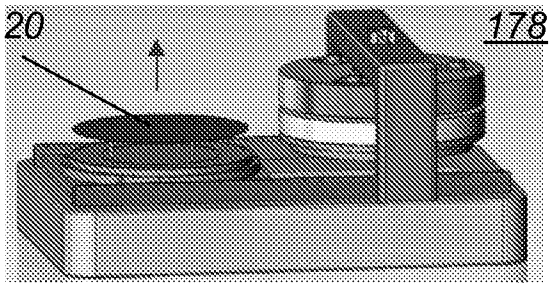


- Controlled thermal slide separation of substrates
  - Top chuck assembly rigidly held
  - Compliant bottom wafer stack

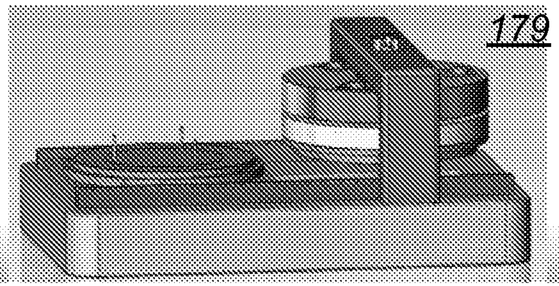
  Twist bottom chuck and
  slide X-axis carriage along 165b



- X-axis carriage indexes to load/unload position
  - Cool debonded wafer
  - Enclosure ensures operator safety

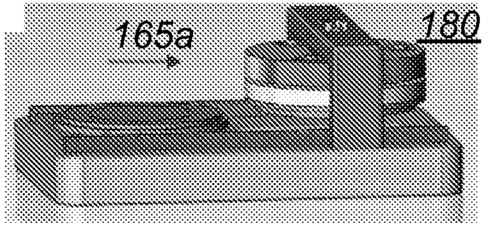


- Primary substrate lift pins up for unload

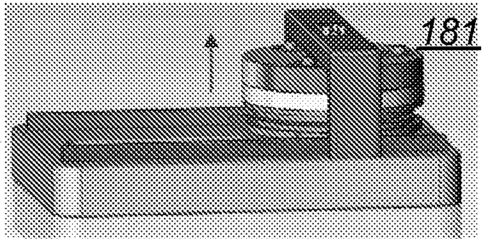


- Remove bottom substrate

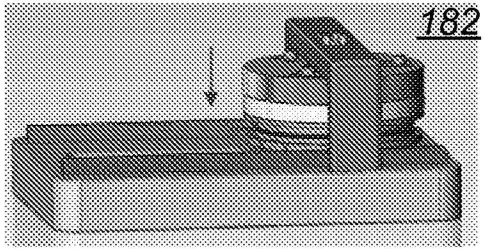
FIG. 26B



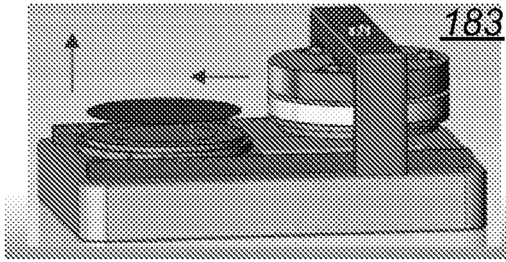
- X-axis carriage indexes back to contact position for carrier wafer removal



- Secondary lift pins up
  - Secondary lift pins contact adhesive side of carrier wafer
  - Air purge on heater to release carrier from heater



- Secondary lift pins down to a fly height above bottom chuck plane as not to contaminate surface with adhesive



- X-axis carriage indexes back to load/unload position for carrier removal
  - Cool carrier wafer
  - Secondary lift pins to up height
  - Remove carrier wafer

FIG. 26C

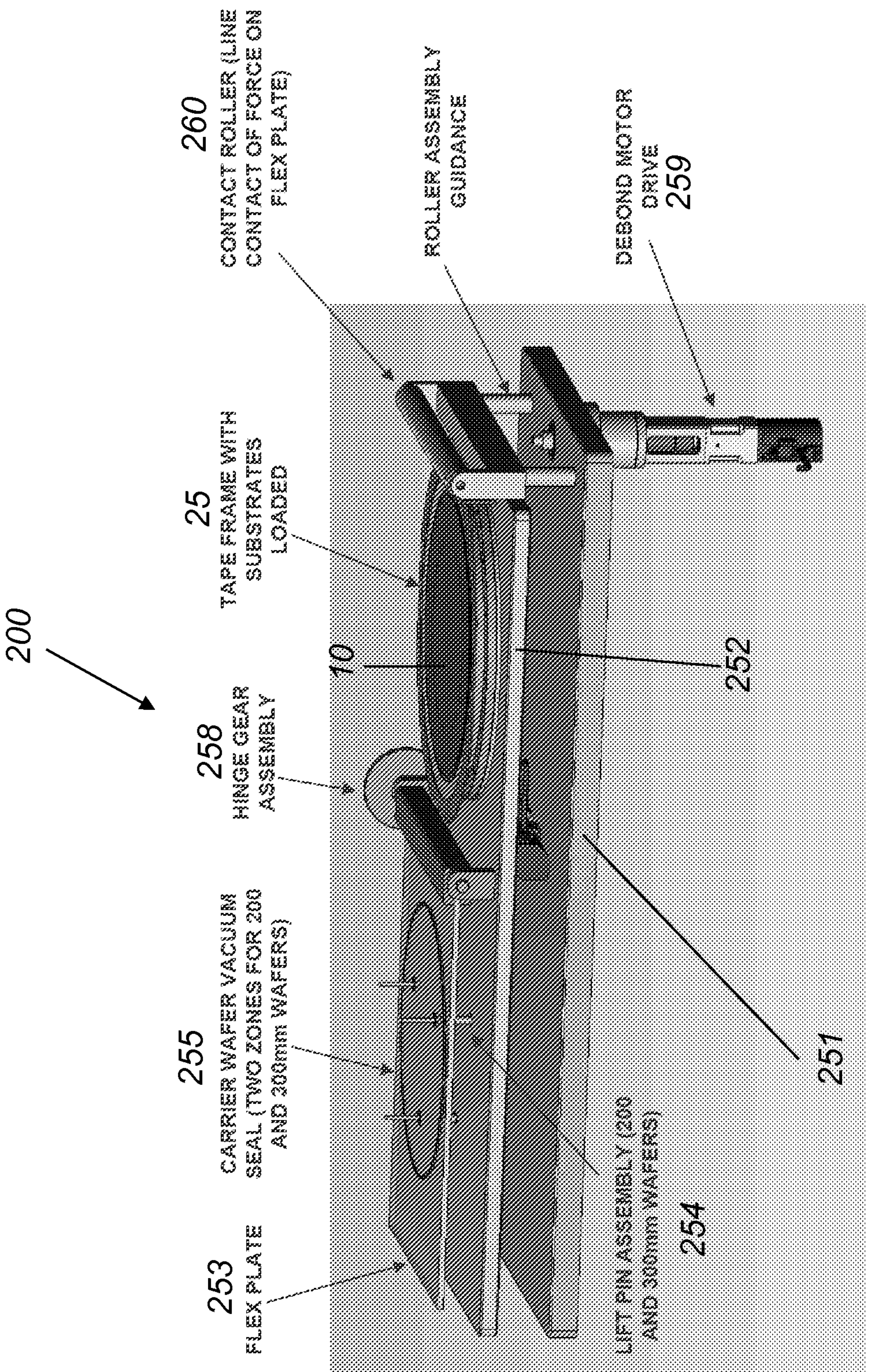

200
260
CONTACT ROLLER (LINE CONTACT OF FORCE ON FLEX PLATE)
ROLLER ASSEMBLY GUIDANCE
DEBOND MOTOR DRIVE
259
25
TAPE FRAME WITH SUBSTRATES LOADED
10
252
258
HINGE GEAR ASSEMBLY
255
CARRIER WAFER VACUUM SEAL (TWO ZONES FOR 200 AND 300mm WAFERS)
251
253
FLEX PLATE
LIFT PIN ASSEMBLY (200 AND 300mm WAFERS)
254

FIG. 27

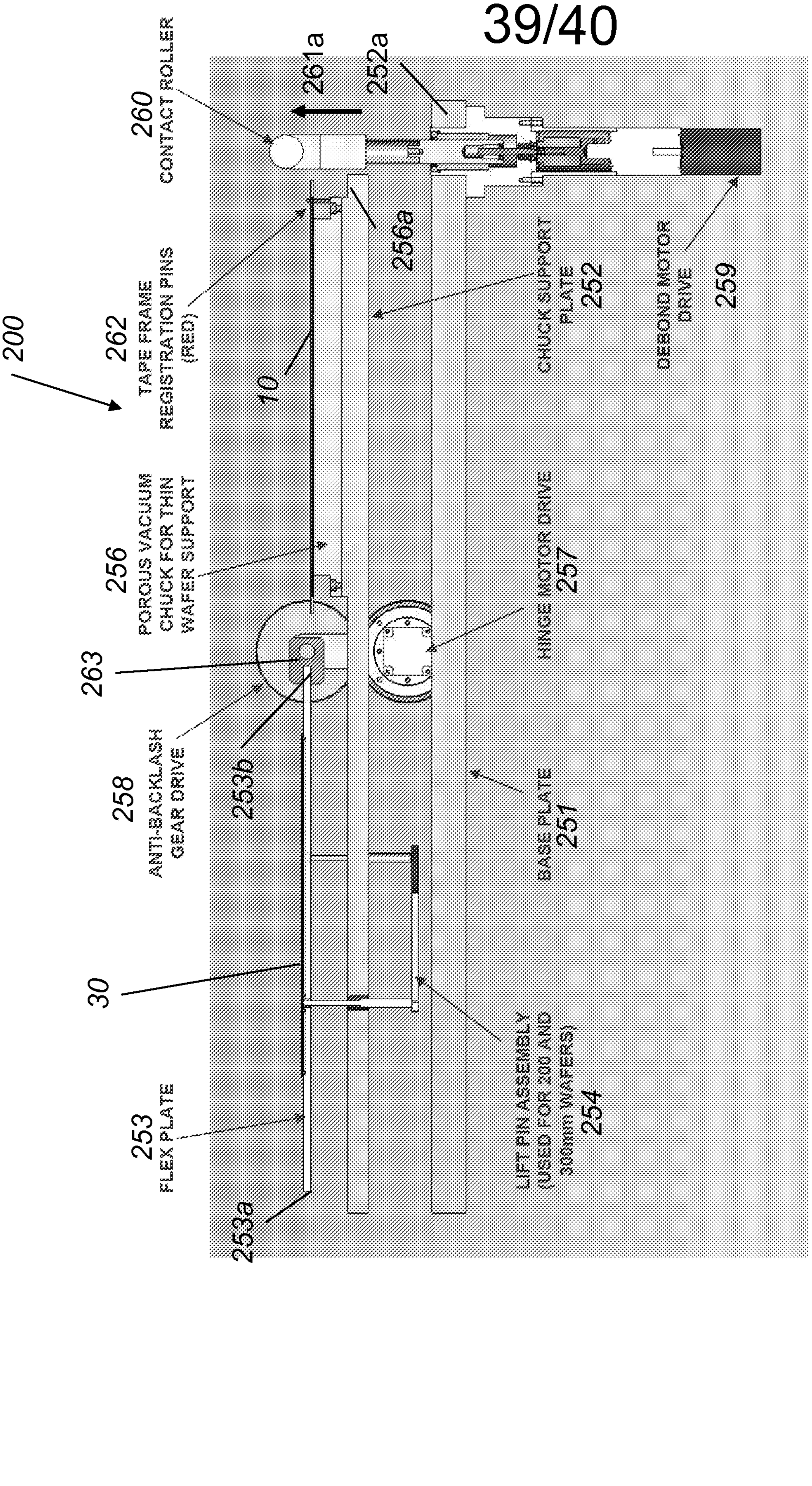
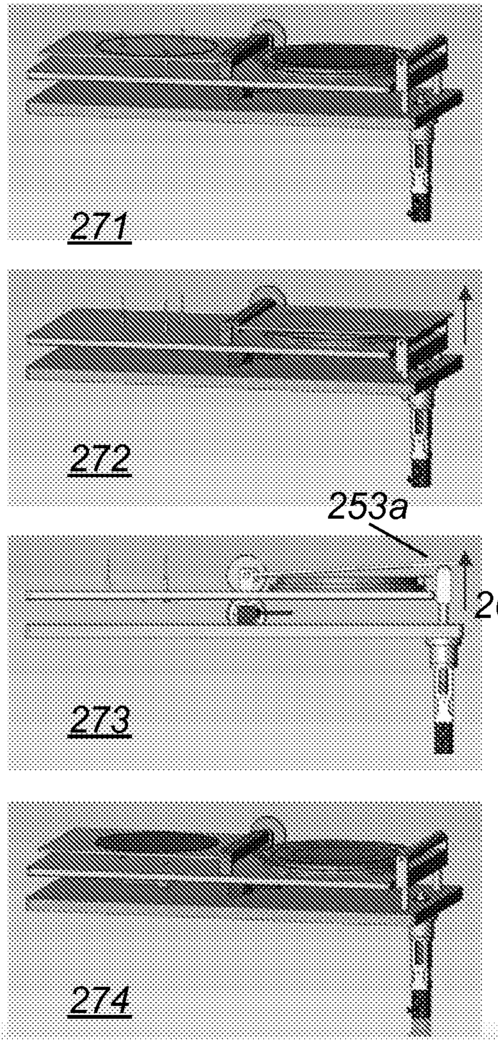

200
260
CONTACT ROLLER
261a
252a
262
TAPE FRAME
REGISTRATION PINS
(RED)
10
256a
CHUCK SUPPORT
PLATE
252
DEBOND MOTOR
DRIVE
259
256
POROUS VACUUM
CHUCK FOR THIN
WAFER SUPPORT
HINGE MOTOR DRIVE
257
263
253b
258
ANTI-BACKLASH
GEAR DRIVE
BASE PLATE
251
30
LIFT PIN ASSEMBLY
(USED FOR 200 AND
300mm WAFERS)
254
253
FLEX PLATE
253a

FIG. 28

270



- Load tape frame with wafer stack
    - Carrier wafer on top
    - Thinned wafer on bottom
  - Index tape frame against registration pins and lock tape frame
  - Pull vacuum on porous chuck to hold tape frame adhesive film
    - Thinned wafer fully supported on porous vacuum chuck

- Engage hinge motor to close flex plate onto wafer stack
  - Pull vacuum on carrier wafer (top) via o-ring/suction cup sealing
  - Holding torque of hinge motor keeps flex plate in "closed position"

- Engage debond motor drive for delamination of wafer stack
  - Plasma activated release layer tuned to release elastomer from thinned wafer first (bottom)
  - Through initial flexing, carrier wafer fully delaminates/debonds from thinned wafer
  - Hold debond motor drive at this position

- Hinge motor opens flex plate in controlled manner to "open position"
  - Release vacuum on carrier wafer
  - Lift pins up to remove carrier wafer with elastomer facing up
  - Release vacuum and unlock tape frame for manual removal

FIG. 29