(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
5 August 2010 (05.08.2010)

PCT

(10) International Publication Number
WO 2010/086796 A2

(51) International Patent Classification:
H01L 21/687 (2006.01) *H01L 21/02* (2006.01)

(21) International Application Number:
PCT/IB2010/050352

(22) International Filing Date:
27 January 2010 (27.01.2010)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
12/361,794 29 January 2009 (29.01.2009) US

(71) Applicant *(for all designated States except US)*: **Lam Research Corporation** [US/US]; 4650 Cushing Parkway, Fremont, California 94538 (US).

(71) Applicant *(for BZ only)*: **Lam Research AG** [AT/AT]; SEZ-Strasse 1, A-9500 Villach (AT).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: **HAO, Fangli, J.** [US/US]; 21920 Eaton Place, Cupertino, California CA-95014 (US).

(74) Agent: **KONTRUS, Gerhard**; SEZ-Strasse 1, A-9500 Villach (AT).

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

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

Declarations under Rule 4.17:

[Continued on next page]

(54) Title: PIN LIFTING SYSTEM

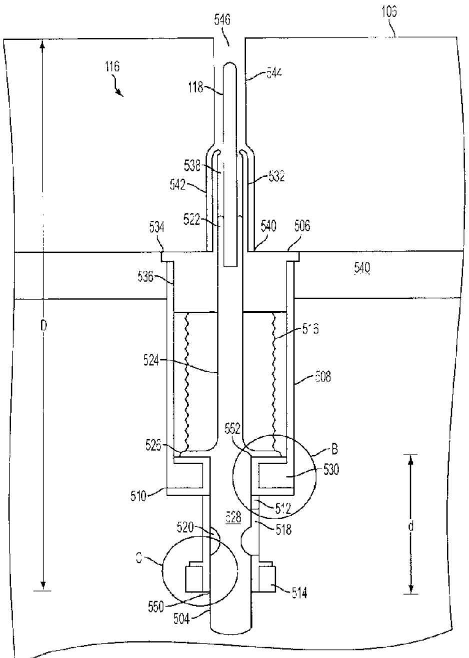

FIG. 5

(57) Abstract: An aspect of the present invention is drawn to a device for use with an electrostatic chuck having a top surface and a bottom surface, the top surface being separated from the bottom surface by a width, the electrostatic chuck additionally having a hole therein, the hole having a first width at the top surface and having a second width at the bottom surface, the first width being less than the second width, the top surface being capable of having wafer disposed thereon. The device includes a pin, a shaft, a neck portion and an outer housing portion. The pin has a pin width less than the first width. The shaft has a pin-holding portion, an end portion and a central portion disposed between the pin-holding portion and the end portion. The central portion has a first bearing portion. The outer housing portion has a first end and a second end and includes a second bearing portion. The shaft is disposed within the outer housing portion and is moveable relative to the outer housing portion. The neck portion is disposed at the first end. The second bearing portion is stationary relative to the neck portion. The first bearing portion is movable relative to the second bearing portion.

WO 2010/086796 A2

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

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

Published:

— *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

PIN LIFTING SYSTEM

BACKGROUND

[0001] Semiconductor wafers are processed in wafer processing systems. An example conventional wafer processing system will now be described with reference to **FIGs. 1** and **2**.

[0002] **FIGs. 1** and **2** illustrate a conventional wafer processing system. In the figures, wafer processing system **100** includes a confinement chamber portion **102**, an electrode **104**, an electrostatic chuck (ESC) **106**, an electrode driving source **112**, an ESC driving source **114** and a pin lifting system **116**. Confinement chamber portion **102** has an input portion **108** and an output portion **110**. Pin lifting system **116** includes a lifting pin **118**. Confinement chamber portion **102** surrounds a processing space **122** used to process a semiconductor wafer **120**.

[0003] In operation, as illustrated in **FIG. 1**, semiconductor wafer **120** is disposed onto ESC **106**. ESC driving source **114** applies a voltage to ESC **106**, thereby creating an electric field, which creates a Coulomb force that holds semiconductor wafer **120** onto ESC **106**. While semiconductor wafer **120** is held in place by ESC **106**, a plurality of materials may be supplied to processing space **122** via input portion **108**, while a voltage is applied to electrode **104** via electrode driving source **112** to create plasma within processing space **122**. The created plasma within processing space interacts with semiconductor wafer **120**, either by etching portions of semiconductor wafer **120**, or by depositing material onto semiconductor wafer **120**. When the process is complete, the remaining material within processing space **122** is removed via output portion **110**. Second driving source **114** then stops applying a voltage to ESC **106**, which terminates the Coulomb force, which then releases semiconductor wafer **120**. As illustrated in **FIG. 2**, pin lifting system **116** then pushes up on semiconductor wafer **120** to relieve the surface tension, lifting one edge of semiconductor wafer **120** off of ESC **106**. Semiconductor wafer **120** is then removed from wafer processing system **100**.

[0004] Great care must be taken in both construction and utilization of wafer processing system **100** in order to maintain the precision required in all aspects of semiconductor wafer processing. ESC **106**, in particular is a very expensive portion of wafer processing system **100**. The operational parameters of ESC **106** must be precisely maintained in order to accurately hold and release semiconductor wafers. Non-limiting examples of operational parameters of ESC **106** include surface resistance, surface capacitance and overall impedance, each of which may be changed as a result to changes, or damage, to the physical integrity of ESC **106**. As such, ESC **106** may not function efficiently, or even at all, if it's physical integrity is degraded.

[0005] ESC **106** is specifically susceptible to damage from lifting pin **118**, as will be described below with respect to **FIGs. 3** and **4**.

[0006] **FIG. 3** is an exploded view of portion A of **FIG. 1**. In **FIG. 3**, lifting pin **118** is separated from the inner wall of ESC **106** by a radial distance **302**. The separation is needed to eliminate contact between lifting pin **118** and ESC **106** thereby preventing damage to ESC **106** from lifting pin **118**.

[0007] **FIG. 4** is an exploded view of an example situation of portion A, when lifting pin **118** is moved closer to semiconductor wafer **120**. In the figure, the longitudinal axis of lifting pin **118** should align perpendicularly with ESC **106**, along line **402**. However, in this example situation, the longitudinal axis of lifting pin **118** is actually aligned along line **404**, which is separated from the axis along line **402** by an angle θ. Because the longitudinal axis of lifting pin **118** is aligned along line **404**, when lifting pin **118** moves close to semiconductor wafer **120**, lifting pin **118** contacts ESC **106** at point **406**. As lifting pin **118** continues to rise toward semiconductor wafer **120**, pin continues to scrape against ESC **106**. Such scraping may damage ESC **106**, which may change the physical integrity of ESC **106**, which may change operational parameters of ESC **106**, and which may result in ESC **106** functioning inefficiently or improperly. In such an event, ESC **106** must be repaired or replaced, either of which is costly.

[0008] A more detailed description of a conventional pin lifting system will now be described with reference to **FIGs. 5** and **6**.

[0009] **FIG. 5** illustrates conventional pin lifting system **116** in a first state. As seen in the figure, pin lifting system **116** includes lifting pin **118**, a pin holding shaft **504**, a housing neck **506**, a housing outer portion **508**, a first bearing **510**, a bearing separating portion **512**, a second bearing **514** and a bellows portion **516**. Bearing separating portion **512** separates first bearing **510** from second bearing **514** and additionally has a window **518** cut therein. Window **518** enables a lifting arm (not shown) to lift pin holding shaft **504** via notch **520**. Pin holding shaft **504** includes a pin holding portion **522**, an intermediate portion **524**, a seat portion **526** and an end portion **528**, which includes notch **520**. Housing neck **506** includes a shaft guiding portion **532**, a cap portion **534** and an inner portion **536**. Housing outer portion **508** includes a lip portion **530**.

[0010] Pin lifting system **116** is mountable into ESC **106** in a mounting hole **540**. Mounting hole **540** includes a neck portion **542**, a pin portion **544** and pin opening **546** at the top surface of ESC **106**. Neck portion **542** is designed to pass lifting pin **118** and to retain shaft guiding portion **532**. Pin portion **544** is operable to pass lifting pin **118**, whereas pin opening **546** is designed to pass the tip of lifting pin **118**. A fastening plate **548** retains pin lifting system **116** within mounting hole **540**.

[0011] Cap portion **534** is connected to housing outer portion **508**. One end of bellows portion **516** is connected to inner portion **536** of housing neck **506**, whereas the other end of bellows portion **516** is connected to seat portion **526**. First bearing **510** is connected to lip portion **530** of housing outer portion **508**, and is additionally connected to bearing separating portion **512**. Bearing separating portion **512** is additionally connected to second bearing **514**. As such, first bearing **510** remains a constant distance *d* from second bearing **514**.

[0012] In this state, lifting pin **118** is disposed below the top surface of ESC **106**. As such, there is a space **538** between the top of pin holding portion **522** and shaft guiding portion **532**.

[0013] A second state, a wafer-lifting state, of pin lifting system **116** will now be described with reference to **FIG. 6**.

[0014] To lift lifting pin **118** out through pin opening **546** of ESC **106**, a lifting arm (not shown) engages and pin holding shaft **504** through window **518** at notch **520**. Pin holding shaft **504** is continually lifted until seat portion **526** is separated from first bearing **510** and the top of pin holding portion **522** reaches the top of shaft guiding portion **532**.

[0015] The problem of a lifting pin damaging an ESC, for example as discussed above with respect to **FIG. 4**, will now be described as applied to pin lifting system **116**, with reference to **FIGs. 7-10**.

[0016] **FIG. 7** is an exploded view of portion B of **FIG. 5**. In the figure, end portion **528** of pin holding shaft **504** does not actually touch first bearing **510**. End portion **528** is spaced a distance **702** from first bearing **510**. Pin lifting system **116** is designed in this manner to provide friction free movement along the axis parallel with the length of pin holding shaft **504**.

[0017] **FIG. 8** is an exploded view of portion C of **FIG. 5**. In the figure, end portion **528** of pin holding shaft **504** does not actually touch bearing separating portion **512**. End portion **528** is spaced a distance **802** from bearing separating portion **512**. Pin lifting system **116** is designed in this manner to provide friction-free movement along the axis parallel with the length of pin holding shaft **504**.

[0018] The outer diameter of pin holding shaft **504** is conventionally designed to be as close to the inner diameter of each of first bearing **510** and bearing separating portion **512** to limit lateral movement of pin holding shaft **504**. However, as discussed above, in order to provide friction-free movement of pin holding shaft **504**, gaps still remain. These gaps may lead to a tilting of lifting pin **118**, as will be described with reference to **FIGs. 9** and **10** below.

[0019] Presume that arrow **902** of **FIG. 9** represents the ideal longitudinal axis of pin holding shaft **504**, wherein the longitudinal axis of lifting pin **118** is normal to the upper surface of ESC **106**. In this example, further presume that pin holding shaft **504** is actually tilted such that end portion **528** touches bearing separating portion **512** at point **550**, as illustrated in **FIG. 5**, whereas end portion **528** additionally touches first bearing **510** at point **552**. In such a case, the longitudinal axis of pin holding shaft **504** actually is parallel with arrow **904** of **FIG. 9**. In this example, therefore, pin holding shaft **504** is tilted by an angle φ.

[0020] As discussed above, the distance d is the distance between first bearing **510** second bearing **514**. The spacing Δ_1 **906** is the spacing between end portion **528** and first bearing **510**, which is additionally illustrated as distance **702** in **FIG. 7**. As such, in **FIG. 9**, distance d and spacing Δ_1 **906** are related to angle φ as:

$$\cos \varphi = \Delta_1 / d. \tag{1}$$

Therefore, with known a distance d and spacing Δ_1 **906**, the maximum tilt angle φ of pin holding shaft **504** may be calculated.

[0021] Once the maximum tilt angle φ of pin holding shaft **504** is calculated, the maximum, unwanted, lateral displacement of lifting pin **118** may be determined. Returning to **FIG. 5**, distance D is the distance from the upper surface of ESC **106** to point **550**, where end portion **528** touches bearing separating portion **512**. Using maximum tilt angle φ of pin holding shaft

504 and the distance *D*, the maximum lateral displacement of lifting pin **118** may be determined.

[0022] As illustrated in **FIG. 10**, presume that arrow **1002** represents the ideal longitudinal axis of pin holding shaft **504**, wherein the longitudinal axis of lifting pin **118** is normal to the upper surface of ESC **106**. In this example, further presume that pin holding shaft **504** is tilted the maximum tilt angle φ. In such a case, the longitudinal axis of pin holding shaft **504** actually is parallel with arrow **1004** of **FIG. 10**. Further, the maximum lateral displacement of lifting pin **118** is Δ_2 **1006**. As such, distance *D* and maximum tilt angle φ are related to Δ_2 **1006** as:

$$\Delta_2 = D \cos \varphi. \tag{2}$$

Therefore, with known a distance *D* and known maximum tilt angle φ, spacing Δ_2 **1006** may be calculated.

[0023] Plugging equation (1) into equation (2), yields:

$$\Delta_2 = (D/d)\, \Delta_1. \tag{3}$$

Therefore, it is clear that the maximum lateral displacement Δ_2 of lifting pin **118** is directly related to the proportion of the distance *D* from the upper surface of ESC **106** to point **550** to the distance *d* between first bearing **510** second bearing **514**.

[0024] As an example, presume that in a conventional pin lifting system, the distance *d* between first bearing **510** second bearing **514** is 1.2 cm, the distance *D* from the upper surface of ESC **106** to point **550** is 4.4 cm and the spacing Δ_1 between end portion **528** and first bearing **510** is 1.4 mm. In such an example, the proportion of the distance *D* from the upper surface of ESC **106** to point **550** to the distance *d* between first bearing **510** second bearing **514** is 3.6. Using equation (3), the maximum lateral displacement Δ_2 of lifting pin **118** is calculated to be 5.1 mm. In other words, lifting pin **118** has 5.1 mm of unwanted lateral play, with which lifting pin **118** may contact and damage ESC **106**.

[0025] What is needed is a pin lifting system that decreases the lateral displacement of the pin.

BRIEF SUMMARY

[0026] It is an object of the present invention to provide a pin lifting system that decreases the lateral displacement of the pin.

[0027] An aspect of the present invention is drawn to a device for use with an electrostatic chuck having a top surface and a bottom surface, the top surface being separated from the bottom surface by a width, the electrostatic chuck additionally having a hole therein, the hole having a first width at the top surface and having a second width at the bottom surface, the first width being less than the second width, the top surface being capable of having wafer disposed thereon. The device includes a pin, a shaft, a neck portion and an outer housing portion. The pin has a pin width less than the first width. The shaft has a pin-holding portion, an end portion and a central portion disposed between the pin-holding portion and the end portion. The central portion has a first bearing portion. The outer housing portion has a first end and a second end and includes a second bearing portion. The shaft is disposed within the outer housing portion and is moveable relative to the outer housing portion. The neck portion is disposed at the first end. The second bearing portion is stationary relative to the neck portion. The first bearing portion is movable relative to the second bearing portion.

[0028] Additional objects, advantages and novel features of the invention are set forth in part in the description which follows, and in part will become apparent to those skilled in the art upon examination of the following or may be learned by practice of the invention. The objects and advantages of the invention may be realized and attained by means of the instrumentalities and combinations particularly pointed out in the appended claims.

BRIEF SUMMARY OF THE DRAWINGS

[0029] The accompanying drawings, which are incorporated in and form a part of the specification, illustrate an exemplary embodiment of the present invention and, together with the description, serve to explain the principles of the invention. In the drawings:

[0030] FIG. 1 illustrates a conventional wafer processing system in a first state when a wafer-lifting pin is below the surface of an ESC;

[0031] FIG. 2 illustrates the conventional wafer processing system in a second state when the wafer-lifting pin is above the surface of the ESC;

[0032] FIG. 3 is an exploded view of portion A of **FIG. 1**;

[0033] FIG. 4 is an exploded view of an example situation of portion A, when the pin is moved closer to semiconductor wafer;

[0034] FIG. 5 illustrates a conventional pin lifting system in a first state;

[0035] FIG. 6 illustrates a conventional pin lifting system in a second state;

[0036] FIG. 7 is an exploded view of portion B of **FIG. 5**;

[0037] FIG. 8 is an exploded view of portion C of **FIG. 5**;

[0038] FIG. 9 illustrates a relationship between an ideal orientation of a pin holding shaft of the conventional pin lifting system of **FIG. 5** when in the first state and an actual orientation of the pin holding shaft when tilted in the first state;

[0039] FIG. 10 illustrates a relationship between an ideal orientation of a pin holding shaft of the conventional pin lifting system of **FIG. 6** when in the second state and an actual orientation of the pin holding shaft when tilted in the second state;

[0040] FIG. 11 illustrates an example pin lifting system, in a first state, in accordance with an aspect of the present invention;

[0041] FIG. 12 illustrates the example pin lifting system of **FIG. 11**, in a second state, in accordance with an aspect of the present invention;

[0042] FIG. 13 is an exploded view of portion D of **FIG. 11**;

[0043] FIG. 14 is an exploded view of portion E of **FIG. 11**;

[0044] FIG. 15 illustrates a relationship between an ideal longitudinal axis of a pin holding shaft of pin lifting system of **FIG. 11** when in the first state and an actual longitudinal axis of the pin holding shaft when tilted in the first state;

[0045] FIG. 16 illustrates a relationship between an ideal longitudinal axis of a pin holding shaft of pin lifting system of **FIG. 12** when in the second state and an actual longitudinal axis of the pin holding shaft when tilted in the second state; and

[0046] FIG. 17 illustrates a relationship between an ideal longitudinal axis of a pin holding shaft of pin lifting system of **FIG. 12** when in the second state and an actual longitudinal axis of the pin holding shaft when tilted in the second state.

DETAILED DESCRIPTION

[0047] An example embodiment of a pin lifting system in accordance with an aspect of the present invention will now be described with reference to **FIGs. 11** and **12**.

[0048] FIG. 11 illustrates an example pin lifting system **1100**, in a first state, in accordance with an aspect of the present invention. As seen in the figure, pin lifting system **1100** includes a pin **1102**, a pin retaining spring **1136**, a pin holding shaft **1104**, a housing neck **1106**, a housing outer portion **1108** that includes a second bearing portion **1112**, a first bearing **1110** and a bellows portion **1116**. Housing outer portion **1108** has a window **1114** cut therein. Window **1114** enables a lifting arm (not shown) to lift pin holding shaft **1104** via a notch **1118**. Pin holding shaft **1104** includes a pin holding portion **1120**, an intermediate portion **1122** that includes a tapered portion **1446**, and an end portion **1124**, which includes an indentation **1126** and notch **1118**. Housing neck **1106** includes a shaft guiding portion **1128**, a cap portion **1130**, an inner portion **1132** that is shaped to have a cavity **1148**. Housing outer portion **1108** includes a lip portion **1134**.

[0049] Pin lifting system **1100** is mountable into ESC **106** in mounting hole **540**. Neck portion **542** is designed to pass pin **1102** and to retain shaft guiding portion **1128**. Pin portion **544** is operable to pass pin **1102**, whereas pin opening **546** is designed to pass the tip of pin **1102**.

[0050] Pin holding portion **1120** has a channel therein, for holding pin **1102**. A radial force providing device, such as a pin retaining spring **1136**, is annularly disposed around pin **1102** and within pin holding portion **1120**. Pin retaining spring **1136** provides a radial force between the circumference of pin **1102** and the inner circumference of pin holding portion **1120**. This radial force centers pin **1102** within pin holding portion **1120**.

[0051] The bottom **1138** of pin **1102** may be designed to have a male geometry, whereas the bottom of pin holding portion **1120**, or pin seat **1140**, may be designed to have a corresponding female geometry. A non-limiting example of a male geometry of pin bottom **1138** includes a semi-spherical convex male geometry, whereas a non-limiting example of a female geometry of pin seat **1140** includes a semi-spherical concave female geometry. This geometric relationship between pin bottom **1138** and pin seat **1140** provides additional centering of pin **1102**.

[0052] Cap portion **1130** is connected to housing outer portion **1108**. One end of bellows portion **1116** is connected to inner portion **1132** of housing neck **1106**, whereas the other end of bellows portion **1116** is connected to first bearing **1110**. First bearing **1110** is additionally connected to intermediate portion **1122** of pin holding shaft **1104**. As will be discussed further below, and in contrast to conventional pin lifting systems as discussed above, first bearing **1110** does not remain at a constant distance *d* from second bearing portion **1112**. In accordance with an aspect of the present invention, first bearing **1110** is movable relative to second bearing portion **1112**.

[0053] In this state, pin **1102** is disposed below the top surface of ESC **106**.

[0054] A second state, a wafer-lifting state, of pin lifting system **1100** will now be described with reference to **FIG. 12**.

[0055] To lift pin **1102** out through pin opening **546** of ESC **106**, a lifting arm (not shown) engages and pin holding shaft **1104** through window **1114** at notch **1118**. Pin holding shaft **1104** is continually lifted until first bearing **1110** is separated from lip portion **1134** and tapered portion **1146** of intermediate portion **1122** of pin holding shaft **1104** fits into neck cavity **1148**.

[0056] **FIG. 13** is an exploded view of portion D of **FIG. 11**. In the figure, first bearing **1110** does not actually touch housing outer portion **1108**. First bearing **1110** is spaced a distance **1302** from housing outer portion **1108**. Pin lifting system **1100** is designed in this manner to provide friction free movement along the axis parallel with the length of pin holding shaft **1104**. First bearing **1110** may additionally be designed to include an annular space **1142**, which may be filled with lubricant to reduce friction in the event first bearing **1110** contacts housing outer portion **1108**.

[0057] **FIG. 14** is an exploded view of portion E of **FIG. 11**. In the figure, end portion **1124** of pin holding shaft **1104** does not actually touch second bearing portion **1112**. End portion **1124** is spaced a distance **1402** from second bearing portion **1112**. Pin lifting system **1100** is designed in this manner to provide friction-free movement along the axis parallel with the length of pin holding shaft **1104**. Second bearing portion **1112** may additionally be designed to include an annular space **1144**, which may be filled with lubricant to reduce friction in the event end portion **1124** contacts second bearing portion **1112**.

[0058] The outer diameter of pin holding shaft **1104** is designed to be as close to the inner diameter of second bearing portion **1112** and the outer diameter of first bearing **1110** is designed to be as close to the inner diameter of outer housing portion **1108** to limit lateral movement of pin holding shaft **1104**. However, as discussed above, in order to provide friction-free movement of pin holding shaft **1104**, gaps still remain. These gaps lead to a tilting of pin **1102**, as discussed below with reference to **FIGs. 15** and **16**.

[0059] In a first state, the pin in a pin lifting system is disposed below the surface of the ESC. Using the example embodiment pin lifting system **1100**, presume that arrow **1502** of **FIG. 15** represents the ideal longitudinal axis of pin holding shaft **1104**, wherein the longitudinal axis of pin **1102** is normal to the upper surface of ESC **106**. In this example, further presume that pin holding shaft **1104** is tilted such that end portion **1124** touches second bearing portion **1112** at point **1146**, as illustrated in **FIG. 11**, whereas first bearing **1110** touches outer housing portion **1108** at point **1148**. In such a case, the longitudinal axis of pin holding shaft **1104** actually is parallel with arrow **1504** of **FIG. 15**. In this example, therefore, pin holding shaft **1104** is tilted by an angle φ'.

[0060] In this example, let *d*' be the distance between first bearing **1110** and second bearing portion **1112**, when pin lifting system **1100** is in the first state. The spacing Δ_1' **1506** is the spacing between first bearing **1110** and outer housing portion **1108**, which is additionally illustrated as distance **1302** in **FIG. 13**. As such, in **FIG. 15**, distance *d*' and spacing Δ_1' **1506** are related to angle φ' as:

$$\cos \varphi' = \Delta_1' / d'. \qquad (4)$$

Therefore, with known a distance *d*' and spacing Δ_1' **1506**, an initial maximum tilt angle φ' of pin holding shaft **1104** may be calculated.

[0061] Unlike the conventional pin lifting system discussed above with respect to **FIGs. 5** and **6**, in a pin lifting system in accordance with an aspect of the present invention, the tilt angle of the pin holding shaft does not remain constant. In particular, and as will be described in more detail below, in a pin lifting system in accordance with an aspect of the present invention, the distance between the first bearing and the second bearing portion does not remain constant. As such, the initial maximum tilt angle φ' of pin holding shaft **1104**, which corresponds to the pin lifting system being in a first state, will be greater than the final maximum tilt angle of pin holding shaft **1104**, which corresponds to the pin lifting system being in a second state.

[0062] In a second state, the pin in a pin lifting system is disposed above the surface of the ESC. Using the example embodiment pin lifting system **1100**, presume that arrow **1602** of **FIG. 16** represents the ideal longitudinal axis of pin holding shaft **1104**, wherein the longitudinal axis of pin **1102** is normal to the upper surface of ESC **106**. In this example, further presume that pin holding shaft **1104** is tilted such that end portion **1124** touches second bearing portion **1112** at point **1146**, as illustrated in **FIG. 12**, whereas first bearing **1110** touches outer housing portion **1108** at point **1248**. In such a case, the longitudinal axis of pin holding shaft **1104** actually is parallel with arrow **1604** of **FIG. 16**. In this example, therefore, pin holding shaft **1104** is tilted by an angle α.

[0063] In this example, let d'' be the distance between first bearing **1110** and second bearing portion **1112**, when pin lifting system **1100** is in the second state. The spacing Δ_1'' **1606** is the spacing between first bearing **1110** and outer housing portion **1108**. As such, in **FIG. 16**, distance d'' and spacing Δ_1'' **1606** are related to angle α as:

$$\cos \alpha = \Delta_1'' / d''. \tag{5}$$

Therefore, with known a distance d'' and spacing Δ_1'' **1606**, a final maximum tilt angle α of pin holding shaft **1104** may be calculated.

[0064] Once the final maximum tilt angle α of pin holding shaft **1104** is calculated, the maximum, unwanted, lateral displacement of pin **1102**, when pin lifting system **1100** is in the second state, may be determined. Returning to **FIG. 12**, distance D'' is the distance from the upper surface of ESC **106** to point **1146**, where end portion **1124** touches second bearing portion **1112**. Using maximum tilt angle α of pin holding shaft **1104** and the distance D'', the maximum lateral displacement of pin **1102** may be determined.

[0065] As illustrated in **FIG. 17**, when pin lifting system **1100** is in the second state, presume that arrow **1702** represents the ideal longitudinal axis of pin holding shaft **1104**, wherein the longitudinal axis of pin **1102** is normal to the upper surface of ESC **106**. In this example, further presume that pin holding shaft **1104** is tilted the maximum tilt angle α. In such a case, the longitudinal axis of pin holding shaft **1104** actually is parallel with arrow **1704** of **FIG. 17**. Further, the maximum lateral displacement of pin **1102** is Δ_2'' **1706**. As such, distance D'' and maximum tilt angle α are related to Δ_2'' **1706** as:

$$\Delta_2'' = D'' \cos \alpha. \tag{6}$$

Therefore, with known a distance D'' and known maximum tilt angle α, spacing Δ_2'' **1706** may be calculated.

[0066] Plugging equation (5) into equation (6), yields:

$$\Delta_2'' = (D''/d'')\,\Delta_1''. \tag{7}$$

Therefore, when pin lifting system **1100** is in the second state, it is clear that the maximum lateral displacement Δ_2'' of pin **1102** is directly related to the proportion of the distance D'' from the upper surface of ESC **106** to point **1146** to the distance d'' between first bearing **1110** and second bearing portion **1112**.

[0067] As an example, presume that in a first state of an example pin lifting system in accordance with the present invention, the distance d' between first bearing **1110** second bearing portion **1112** is 1.2 cm and the spacing Δ_1' between first bearing **1110** and outer housing portion **1108** is 1.4 mm. In such an example, using equation (4) the initial maximum tilt angle φ' would be 1.8°.

[0068] However, when in the second state, the final maximum tilt angle α is smaller than the initial maximum tilt angle φ'.

[0069] Presume that in a second state of an example pin lifting system in accordance with the present invention, the distance d'' between first bearing **1110** second bearing portion **1112** is now 2.0 cm because first bearing **1110** has moved relative to second bearing portion **1112**. Further, presume that the distance D'' from the upper surface of ESC **106** to point **1146** is 4.4 cm and the spacing Δ_1' between first bearing **1110** and outer housing portion **1108** remains 1.4 mm. In such a case, the proportion of the distance D'' from the upper surface of ESC **106** to point **1112** to the distance d'' between first bearing **1110** second bearing portion **1112** is 2.2. Using equation (7), the maximum lateral displacement Δ_2'' of pin **1102**, when pin lifting system **1100** is in the second state, is calculated to be 3.08 mm. In other words, pin **1102** has 3.08 mm of unwanted lateral play, with which pin **1102** may contact and damage ESC **106**. This is a 40% decrease in lateral play over the conventional pin lifting system discussed above.

[0070] A pin lifting system in accordance with aspect of the present invention decreases the maximum lateral movement of the lifting pin, when the pin lifting system in is a state where the pin is close to the surface of the ESC. A radial force providing device within the pin holding portion of the pin holding shaft provides additional centering of the pin. Further, a collaboration of geometries of the bottom of the pin and the pin seat within the pin holding portion of the pin holding shaft provides addition centering of the pin. Finally, by varying the distance between a first bearing and a second bearing portion of the pin lifting system, the final maximum lateral movement of the lifting pin is decreased.

[0071] The foregoing description of various preferred embodiments of the invention have been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise forms disclosed, and obviously many modifications and variations are possible in light of the above teaching. The exemplary embodiments, as described above, were chosen and described in order to best explain the principles of the invention and its practical application to thereby enable others skilled in the art to best utilize the invention in various embodiments and with various modifications as are suited to the particular use contemplated. It is intended that the scope of the invention be defined by the claims appended hereto.

CLAIMS

What is claimed as new and desired to be protected by Letters Patent of the United States is:

1. A device for use with an electrostatic chuck having a top surface and a bottom surface, the top surface being separated from the bottom surface by a width, the electrostatic chuck additionally having a hole therein, the hole having a first width at the top surface and having a second width at the bottom surface, the first width being less than the second width, the top surface being capable of having wafer disposed thereon, said device comprising:

a pin having a pin width less than the first width;

a shaft having a pin-holding portion, an end portion and a central portion disposed between said pin-holding portion and said end portion, said central portion comprising a first bearing portion;

a neck portion; and

an outer housing portion having a first end and a second end and comprising a second bearing portion,

wherein said shaft is disposed within said outer housing portion and is moveable relative to said outer housing portion,

wherein said neck portion is disposed at said first end,

wherein said second bearing portion is stationary relative to said neck portion, and

wherein first bearing portion is movable relative to said second bearing portion.

2. The device of claim 1,

wherein said pin comprises a first pin end and a second pin end,

wherein said first pin end is separated from said second pin end by a pin length,

wherein said second pin end comprises a male geometry,

wherein said pin-holding portion comprises a channel portion having an open end and a pin-holding bottom separated from said open end by a pin-holding length,

wherein said pin-holding bottom comprises a female geometry, and

wherein said pin is disposed in said pin-holding portion such that second pin end rests on said pin-holding bottom.

3. The device of claim 2,

wherein said second pin end comprises a semi-spherical convex male geometry

wherein said pin-holding bottom comprises a semi-spherical concave female geometry.

4. The device of claim 2, further comprising a radial force-providing device disposed to surround said pin and disposed within said pin-holding portion, said radial force-providing device operable to provide a radial force between said pin-holding portion and said pin.

5. The device of claim 1,

wherein said pin comprises a first pin end and a second pin end,

wherein said first pin end is separated from said second pin end by a pin length,

wherein said shaft is moveable between a first position and a second position,

wherein when said shaft is disposed in the first position, the first pin end is disposed between the top surface and said second pin end and the first bearing portion is disposed a first bearing separation distance from said second bearing portion,

wherein when said shaft is disposed in the second position, the top surface is disposed between said first pin end and said second pin end, and the first bearing portion is disposed a second bearing separation distance from said second bearing portion, and

wherein the first bearing separation distance is greater than the second bearing separation distance.

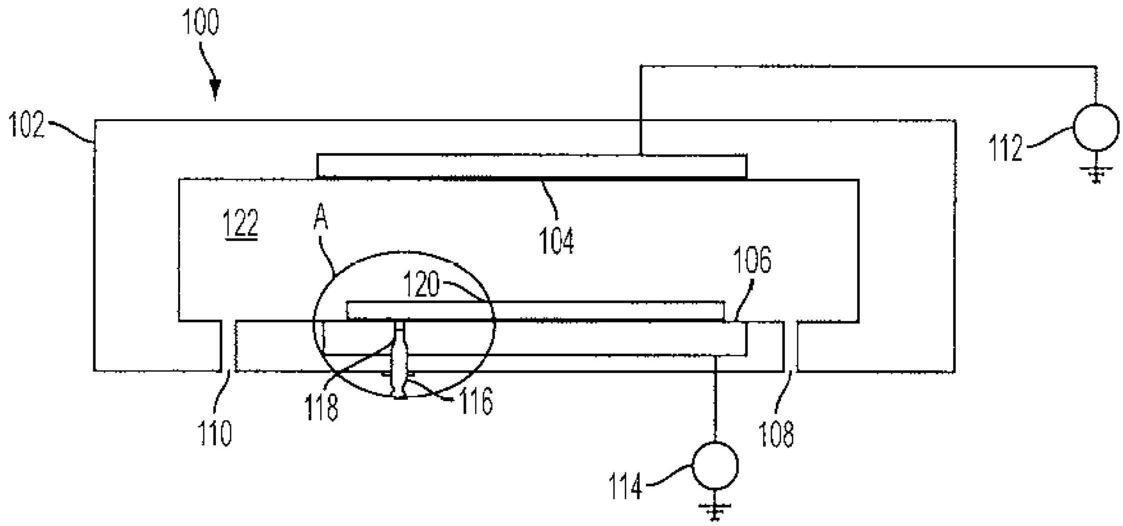
100
102
112
122
A
104
106
120
118
116
110
108
114

FIG. 1

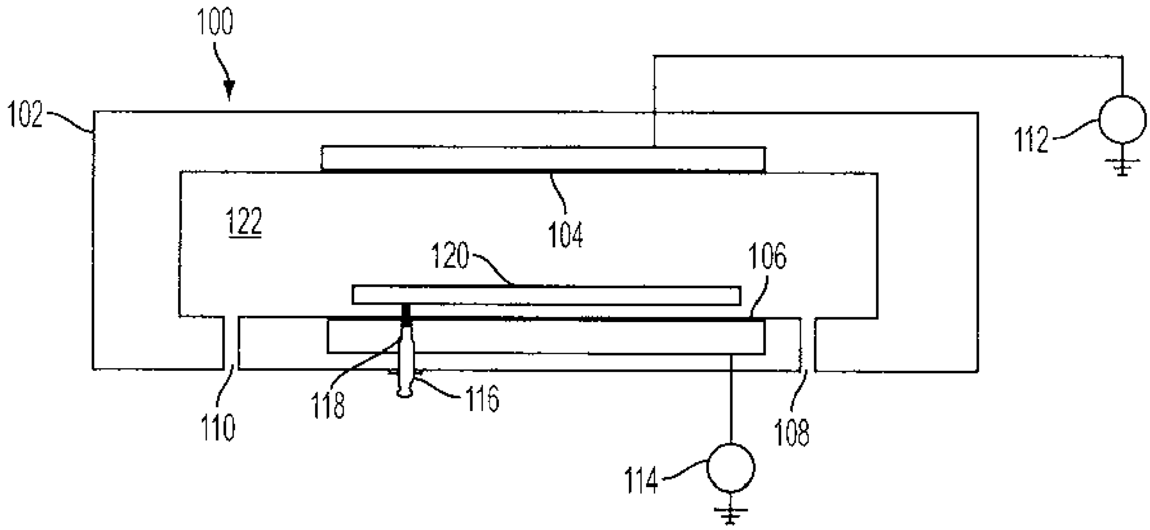
100
102
112
122
104
120
106
118
116
110
108
114

FIG. 2

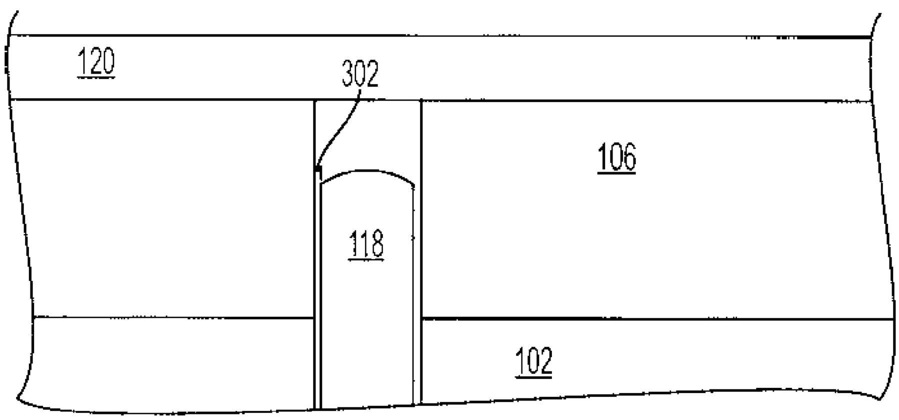

FIG. 3

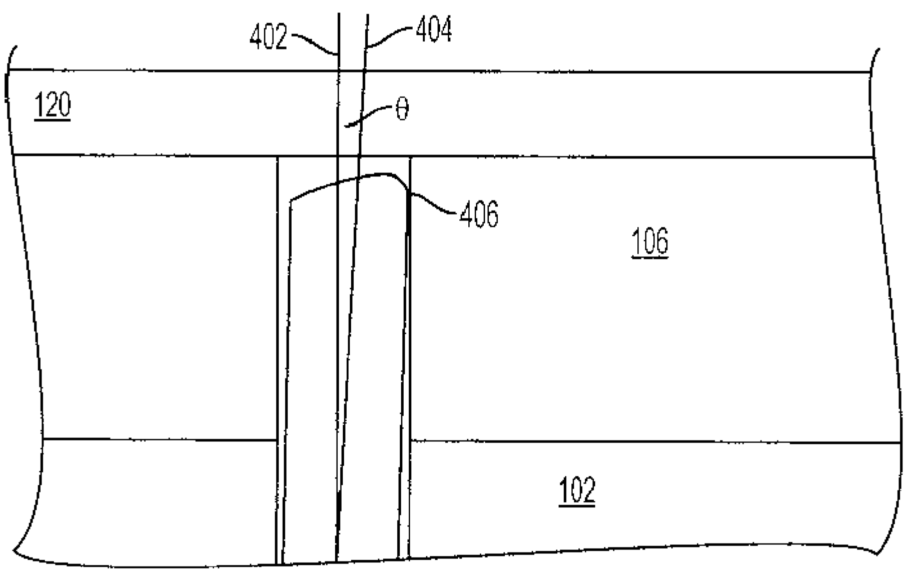

FIG. 4

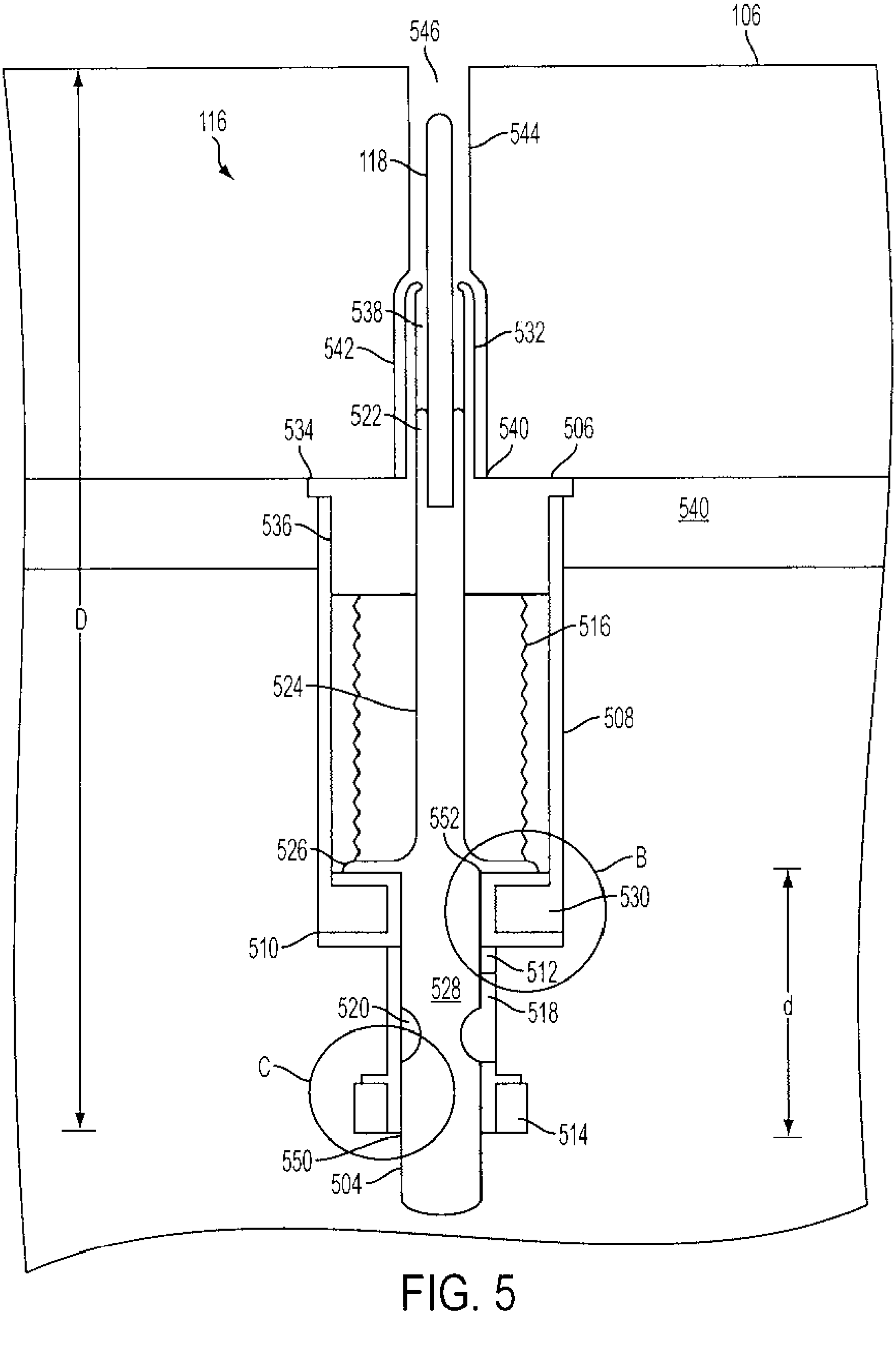
546
106
116
544
118
538
532
542
522
534
540
506
540
536
516
524
508
552
526
B
530
510
512
528
520
518
d
C
514
550
504
D

FIG. 5

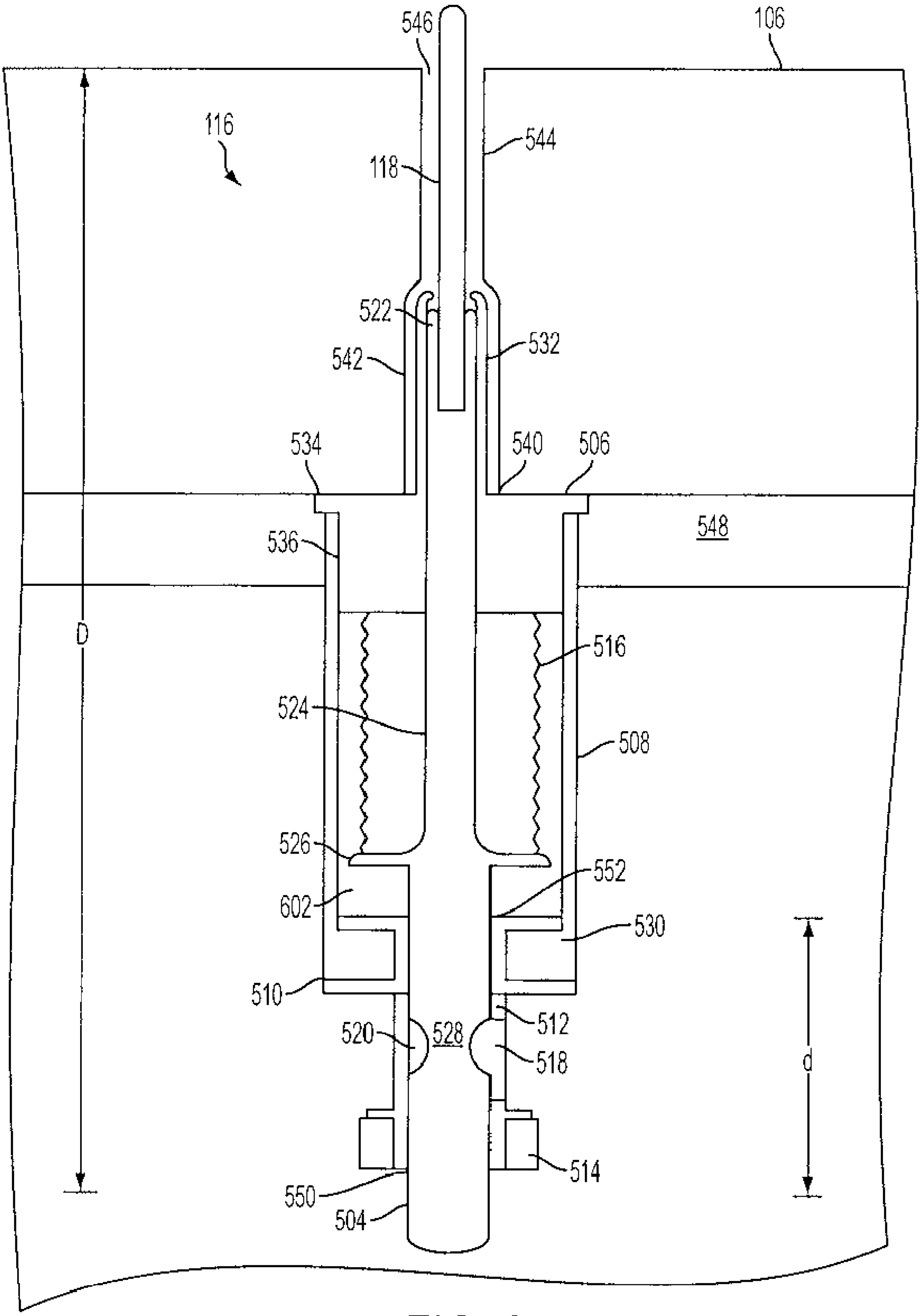
546
106
116
118
544
522
532
542
534
540
506
536
548
D
516
524
508
526
552
602
530
510
512
520
528
518
d
514
550
504

FIG. 6

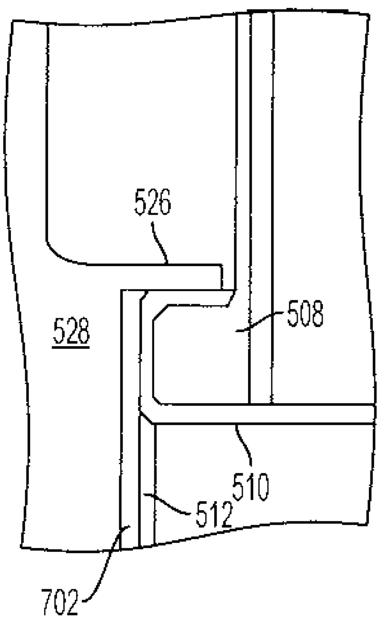

FIG. 7

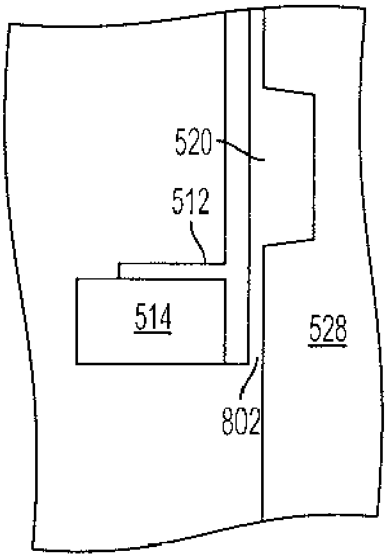

FIG. 8

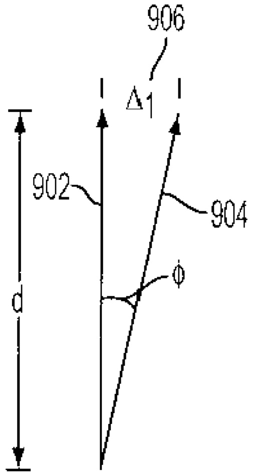

FIG. 9

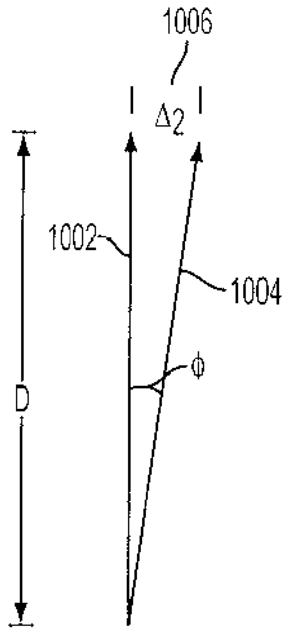

FIG. 10

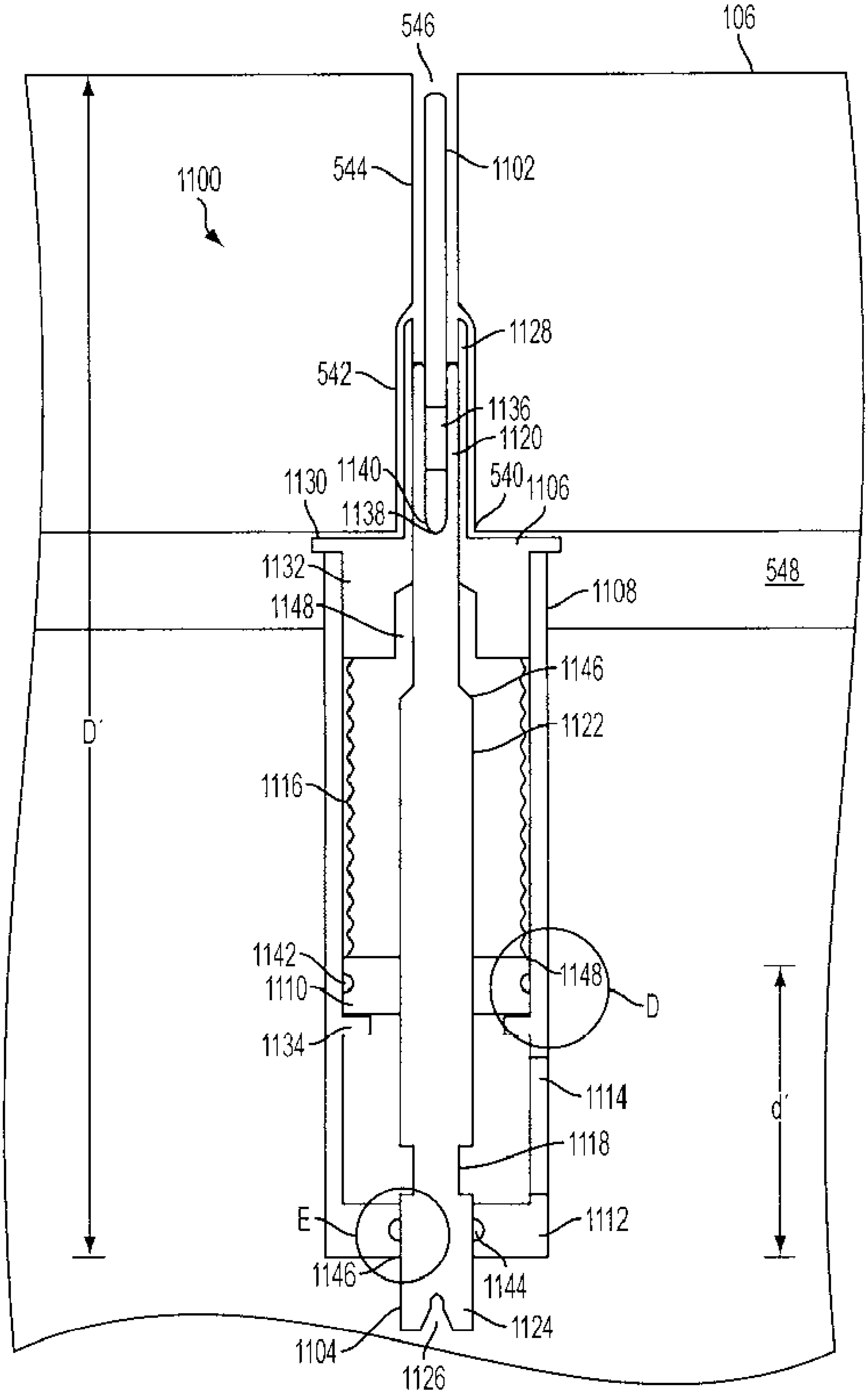
546
106
1100
544
1102
1128
542
1136
1120
1130
1140
540
1106
1138
1132
548
1148
1108
1146
1122
D´
1116
1142
1110
1148
D
1134
1114
d´
1118
E
1112
1146
1144
1124
1104
1126

FIG. 11

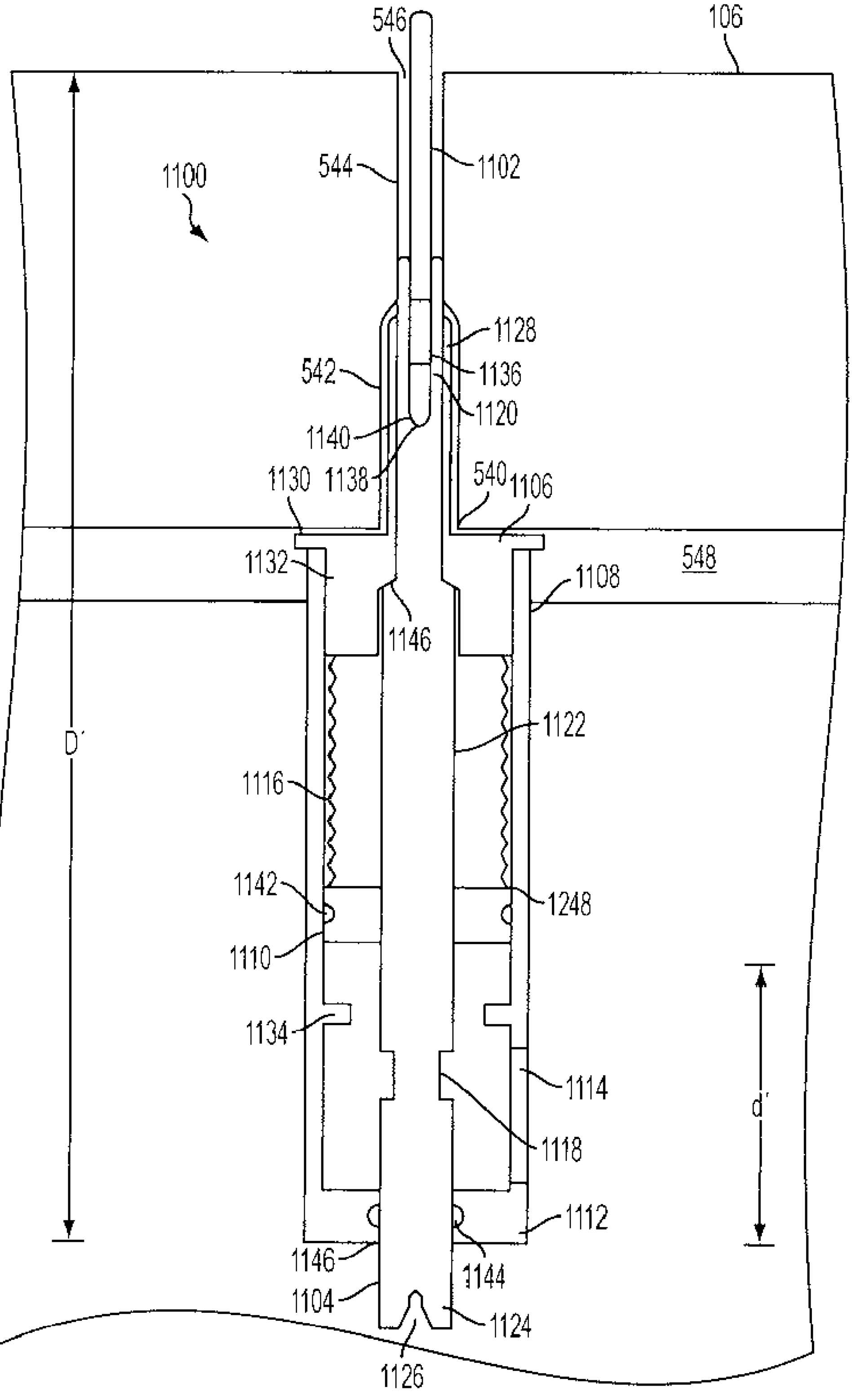
546
106
544
1102
1100
1128
542
1136
1120
1140
1130
1138
540
1106
1132
548
1108
1146
1122
D'
1116
1142
1248
1110
1134
1114
d'
1118
1112
1146
1144
1104
1124
1126

FIG. 12

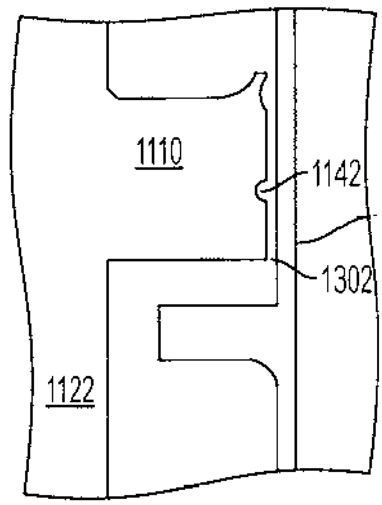

FIG. 13

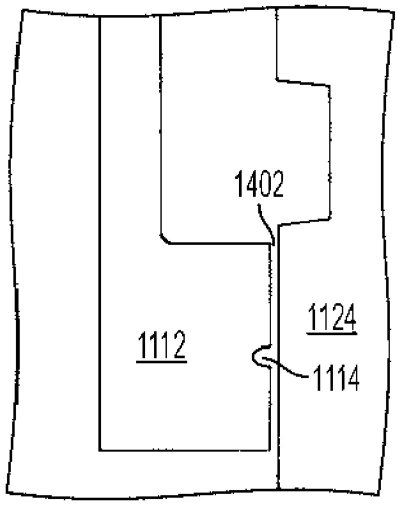

FIG. 14

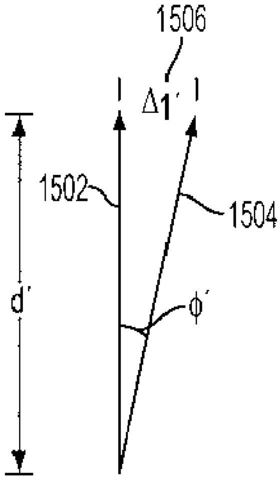

FIG. 15

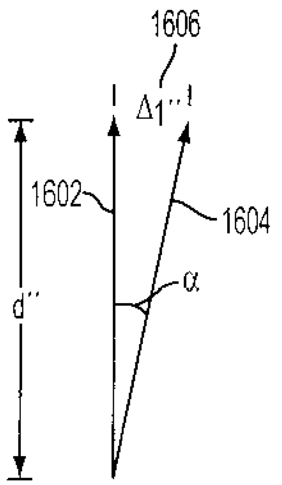

FIG. 16

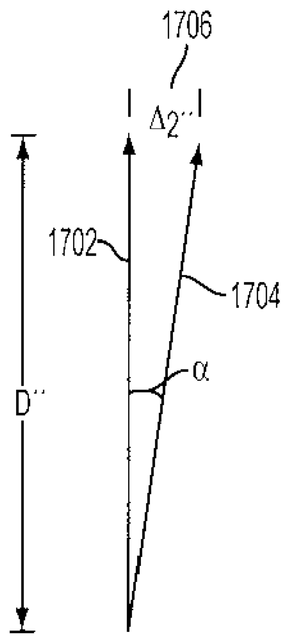

FIG. 17