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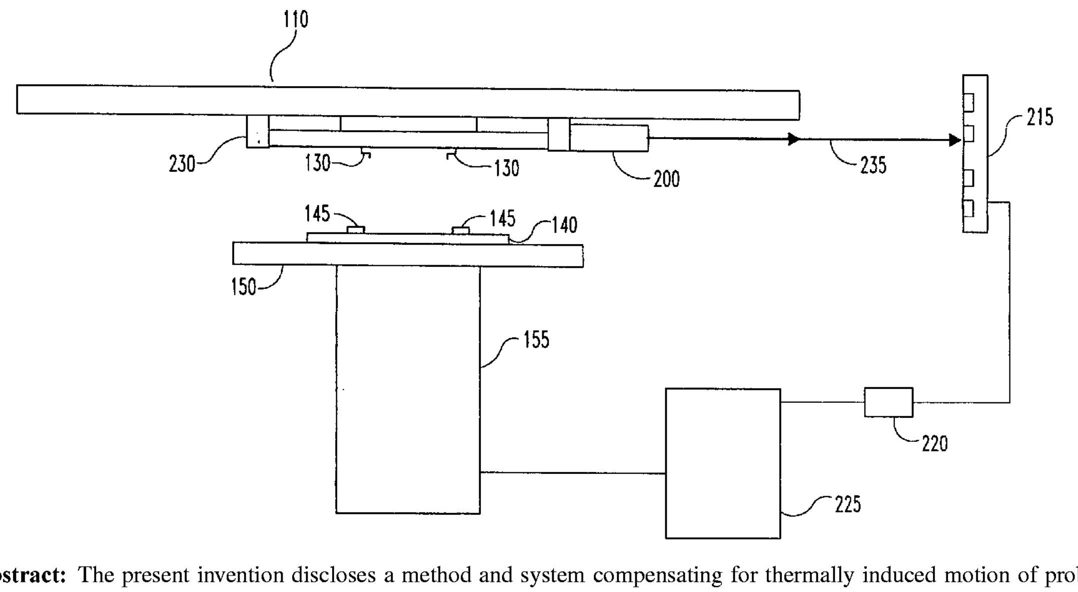
(54) Title: METHOD AND SYSTEM FOR COMPENSATING THERMALLY INDUCED MOTION OF PROBE CARDS



(57) Abstract: The present invention discloses a method and system compensating for thermally induced motion of probe cards used in testing die on a wafer. A probe card incorporating temperature control devices to maintain a uniform temperature throughout the thickness of the probe card is disclosed. A probe card incorporating bi-material stiffening elements which respond to changes in temperature in such a way as to counteract thermally induced motion of the probe card is disclosed including rolling elements, slots and lubrication. Various means for allowing radial expansion of a probe card to prevent thermally induced motion of the probe card are also disclosed. A method for detecting thermally induced movement of the probe card and moving the wafer to compensate is also disclosed.

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METHOD AND SYSTEM FOR COMPENSATING THERMALLY INDUCED MOTION OF PROBE CARDS

BACKGROUND OF THE INVENTION

The present invention relates to probe cards having electrical contacts for testing integrated circuits, and more specifically for a system and method to compensate for thermally induced motion of such probe cards. Probe cards are used in testing a die, e.g. integrated circuit devices, typically on wafer boards. Such probe cards are used in connection with a device known as a tester (sometimes called a prober) wherein the probe card is electronically connected to the tester device, and in turn the probe card is also in electronic contact with the integrated circuit to be tested.

Typically the wafer to be tested is loaded into the tester securing it to a movable chuck. During the testing process, the chuck moves the wafer into electrical contract with the probe card. This contact occurs between a plurality of electrical contacts on the probe card, typically in the form of microsprings, and plurality of discrete connection pads (bond pads) on the dies. Several different types of electrical contacts are known and used on probe cards, including without limitation needle contacts, cobra-style contacts, spring contacts, and the like. In this manner, the semiconductor dies can be tested and exercised, prior to singulating the dies from the wafer.

For effective contact between the electrical contacts of the probe card and the bond pads of the dies, the distance between the probe card and the wafer should be carefully maintained. Typical spring contacts such as those disclosed in U.S. Patent Nos. 6,184,053 B1, 5,974,662 and 5,917,707, incorporated herein by reference, are approximately 0.040", or about one millimeter, in height. If the wafer is too far from the probe card contact between the electrical contacts and the bond pads will be intermittent if at all.

While the desired distance between the probe card and wafer may be more easily achieved at the beginning of the testing procedure, the actual distance may change as the testing procedure proceeds, especially where the wafer temperature differs from the ambient temperature inside the tester. In many instances, the wafer being tested may be heated or cooled during the testing process. Insulating material such as platinum reflectors may be used to isolate the effects of the heating or cooling process to some extent, but it cannot eliminate them entirely. When a wafer of a temperature greater than that of the probe card is moved under the card, the card face nearest the wafer begins to change temperature. Probe cards are typically built of layers of different materials and are usually poor heat conductors in a direction normal to the face of the card. As a result of this a thermal gradient across the thickness of the probe card can appear rapidly. The probe card deflects from uneven heat expansion. As a result of this uneven expansion, the probe card begins to sag, decreasing the distance between the probe card and the wafer. The opposite phenomenon occurs when a wafer is cooler than the ambient temperature of the tester is placed near the probe card. As the face of the probe card nearest the wafer cools and contracts faster than the face farthest from the wafer, the probe card begins to bow away from the wafer disrupting electrical contact between the wafer and the probe card.

SUMMARY OF THE INVENTION

The invention is set forth in the claims below, and the following is not in any way to limit, define or otherwise establish the scope of legal protection. In general terms, the present invention relates to a method and system from compensating for thermally or otherwise induced motion of probe cards during testing of integrated circuits. This may include optional features such as energy transmissive devices, bi-material deflecting elements, and/or radial expansion elements.

One object of the present invention is to provide an improved method and system for compensating thermally induced motion of probe cards.

Further objects, embodiments, forms, benefits, aspects, features and advantages of the present invention may be obtained from the present disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross-sectional view of a probe card.

FIG. 2 is a cross-sectional view of a probe card engaged with a wafer.

FIG. 2A is a cross-sectional view of a thermally distorted probe card engaged with a wafer.

FIG. 2B is a cross-sectional view of a thermally distorted probe card engaged with a wafer.

FIG. 3 is a cross-sectional view of a probe card assembly.

FIG. 4 is an exploded, cross-sectional view of a probe card according to one example of the present invention.

FIG. 4A is a cross-sectional view of the probe card of FIG. 4.

FIG. 4B is a top plan view of another example of a probe card according to the present invention.

FIG. 5 is an exploded, cross-sectional view of a probe card according to another example of the present invention.

FIG. 5A is a cross-sectional view of the probe card of FIG. 5.

FIG. 6 is an exploded, cross-sectional view of a probe card according to another example of the present invention.

FIG. 6A is a cross-sectional view of the probe card of FIG. 6.

FIG. 6B is a bottom plan view of the probe card of FIG. 6.

FIG. 7 is an exploded, cross-sectional view of a probe card according to another example of the present invention.

FIG. 7A is a cross-sectional view of the probe card of FIG. 7.

FIG. 8 is a cross-sectional view of a probe card according to yet another example of the present invention.

FIG. 9 is an exploded, cross-sectional view of a probe card according to another example of the present invention.

FIG. 9A is a cross-sectional view of the probe card of FIG. 9.

FIG. 10 is a flowchart depicting one example of a control program according to the present invention.

FIG. 11 is a front diagrammatic view of a prober and a tester connected by two communications cables according to one embodiment of the present invention.

FIG. 12 is a side diagrammatic view of the prober of FIG. 11.

FIG. 13 A is a top plan view of another example of a probe card according to the present invention.

FIG. 13 B is a cross-sectional view of the probe card of FIG. 13A.

FIG. 14 A is a top plan view of another example of a probe card according to the present invention.

FIG. 14 B is a cross-sectional view of the probe card of FIG. 14A.

FIG. 15 A is a top plan view of another example of a probe card according to the present invention.

FIG. 15 B is a cross-sectional view of the probe card of FIG. 15A.

FIG. 16 A is a top plan view of another example of a probe card according to the present invention.

FIG. 16 B is a cross-sectional view of the probe card of FIG. 16A.

FIG. 17 A is a top plan view of another example of a probe card according to the present invention.

FIG. 17 B is a cross-sectional view of the probe card of FIG. 17A.

FIG. 18 A is a top plan view of another example of a probe card according to the present invention.

FIG. 18 B is a cross-sectional view of the probe card of FIG. 18A.

FIG. 19 A is a top plan view of another example of a probe card according to the present invention.

FIG. 19 B is a cross-sectional view of the probe card of FIG. 19A.

FIG. 20 A is a top plan view of another example of a probe card according to the present invention.

FIG. 20 B is a cross-sectional view of the probe card of FIG. 20A.

FIG. 21 A is a top plan view of another example of a probe card according to the present invention.

FIG. 21 B is a cross-sectional view of the probe card of FIG. 21A.

FIG. 22 A is a top plan view of another example of a probe card according to the present invention.

FIG. 22 B is a cross-sectional view of the probe card of FIG. 22A.

FIG. 23 A is a top plan view of another example of a probe card according to the present invention.

FIG. 23 B is a cross-sectional view of the probe card of FIG. 23A.

FIG. 24 A is a top plan view of another example of a probe card according to the present invention.

FIG. 24 B is another top plan view of another example of a probe card according to the present invention.

FIG. 24 C is another top plan view of another example of a probe card according to the present invention.

FIG. 25 is a top plan view of another example of a probe card according to the present invention.

FIG. 26 is a front diagrammatic view of a tester using an optical motion detection system according to one embodiment of the present invention.

FIG. 27 is a front diagrammatic view of a tester using an optical motion detection system according to another embodiment of the present invention.

FIG. 28 is a front diagrammatic view of a tester using an optical motion detection system according to another embodiment of the present invention.

FIG. 28A is a top plan view of the optical motion detection system of FIG. 28.

FIG. 29 is a front diagrammatic view of a tester using an optical motion detection system according to another embodiment of the present invention.

FIG. 30 is a front diagrammatic view of a tester using an optical motion detection system according to another embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

For the purposes of promoting an understanding of the principles of the invention, reference will now be made to the embodiments illustrated in the drawings and specific language will be used to describe the same. It will nevertheless be understood that no limitation of the scope of the invention is thereby intended, and alterations and modifications in the illustrated device and method and further applications of the principles of the invention as illustrated therein, are herein contemplated as would normally occur to one skilled in the art to which the invention relates.

FIG. 1 shows a typical example of a probe card 110 and wafer 140 loaded into a tester. In this and the other accompanying views certain elements of certain components are shown exaggerated, for illustrative clarity. Additional components which may be mounted to the probe card, such as active and passive electronic components, connectors, and the like, are omitted for clarity. The present invention may be practiced with variations of the basic probe card design examples shown, such as probe cards incorporating interposers as shown in U.S. Patent No. 5,974,662, which is hereby incorporated by reference. No limitation of the scope of the invention is intended by the omission of these elements.

The probe card 110 is supported by the head plate 120 when mounted in the tester parallel to the die on a wafer 140, and most typically positioned directly above it. The probe card 110 is typically round, having a diameter on the order of 12 inches, although other sizes and shapes are also contemplated. The probe card 110 is generally a conventional circuit board substrate having a plurality (two of many shown) of electrical contacts 130 disposed on the wafer side 114 thereof. The electrical contacts are known in the industry and hereinafter referred to as "probes" or "probe elements". A preferred type of probe element is spring contacts, examples of which are disclosed in U.S. Patent Nos. 6,184,053 B1; 5,974,662; and 5,917,707 which are hereby incorporated by reference. However, many other contacts are known in the industry (e.g., needle contacts and cobra-style contacts) and any such contact may be included in any embodiment of the probe cards of the present invention. Typically, the probe card is connected to the testing machine by other electrical contacts (not shown).

As is known, a semiconductor wafer 140 includes a plurality of die sites (not shown) formed by photolithography, deposition, diffusion, and the like, on its front (upper, as viewed) surface. Each die site typically has a plurality (two of many shown) of bond pads 145, which may be disposed at any location and in any pattern on the surface of the die site. Semiconductor wafers typically have a diameter of at least 6 inches, but the use of the present invention to test wafers of other sizes and shapes is also contemplated.

Once the wafer 140 is mounted in the testing device, wafer chuck 150 including table actuator 155 lift the integrated wafer 140 vertically in the Z-axis direction (see FIG. 2) to allow electronic contact between probes 130 and a corresponding pad (such as pads 145) of the wafer 140. The lifting mechanism may utilize a scissors mechanism, telescoping action, lever action, thread action, cam action or other lifting mechanisms. Such lifting mechanism, as with the other movements in the other embodiments, may be actuated by a variety of mechanisms such as pneumatics, stepper motors, servo motors or other electrical motors or otherwise and are typically robotically controlled. Such lifting mechanism may also allow for movement in the X and Y directions, tilt, and rotation. Once the wafer 140 is moved into electrical contact with the probe card 110 (as shown in FIG. 2), the testing procedure may proceed.

FIG. 2 illustrates a wafer 140 in electrical contact with a probe card 110. The pressure contact of the probe elements 130 with the bond pads 145 provide this contact. For this contact to be produced, the wafer 140 is urged to an effective distance Z (vertical as shown) from the probe card. Typically, the height of the probes 130 used in the probe card is approximately 0.040", or about one millimeter, although probe card contacts of other heights are also contemplated by the present invention. As the probes 130 are generally somewhat flexible, the effective distance Z between the probe card 110 and the wafer 140 may differ from the height of the probes 130 being used. Of course the present invention naturally may be modified in accordance with the particular height or type of a particular probe card's electrical contacts.

FIGS. 2A and 2B illustrate the thermally induced motion of probe cards the present invention is directed towards. As shown in FIG. 2A, a wafer 140 having a temperature greater than the ambient temperature of the tester is engaged with the probe card 110. The card face nearest the wafer 114 begins to change temperature. As probe card assemblies are typically poor conductors of heat in a direction normal to the face of the card, a thermal gradient rapidly develops across the thickness of the probe card. The probe card behaves as a bimetallic element as the face nearest the wafer 114 warms and therefore expands more quickly than the face farthest from the wafer 112. As a result of this uneven expansion the probe card begins to sag. This movement decreases the actual distance Z' between the probe card 110 and the wafer 140 to something less than the optimal effective distance. Decreasing the distance between the probe card 110 and the wafer 140 may result in movement of the probes 130 leading to overengagement of the probes 130 from the bond pads 145 and possibly deformation or even breaking the probe elements 130 or the semiconductor device being tested.

The opposite phenomenon occurs when a wafer 140 significantly cooler than the ambient temperature of the tester is placed near the probe card 130. As the face of the probe card nearest the wafer 114 cools it begins to contract faster than the face farthest from the wafer 112. As a result of this uneven cooling, the probe card 110 begins to bow away from the wafer creating an actual distance Z' between the wafer 140 and the probe card 110 greater than the optimal effective distance. If great enough this bow may disrupt electrical contact between the wafer 140 and the probe card 110 by disengaging some of the probes 130 from their corresponding bond pads 145.

As seen in FIG. 3, one solution to the problem of thermally induced or other motion of probe cards known in the art is the addition of stiffening elements 360, 365 to the probe card 110. Typically circular and made of metal, both wafer side stiffeners 360 and tester side stiffeners 365 are commonly employed. These stiffeners may be affixed in any suitable manner, such as with screws (not shown) extending through corresponding holes (not shown) through the probe card 110, thereby capturing the probe card 110 securely between the wafer side stiffener 360 and tester side stiffener 365. The stiffeners may also be individually mounted directly to the probe card 110 such as with screws (not shown). The use of stiffeners, however, may also lead to thermally induced movement of the probe card. As the metal stiffeners conduct heat better than the probe card 110, a thermal gradient can appear causing the metal stiffener on one side of the probe card 110 to expand more than the metal stiffener on the other side of the probe card 110.

FIG. 4 shows an exploded, cross-sectional view of one example of the present invention. Although certain elements have been exaggerated for clarity, the dashed lines in the figure properly indicate the alignment of the various components. This example is a probe card assembly incorporating at least one energy transmissive device 470, 475 to compensate for thermally induced motion of the probe card. At least one such energy transmissive element 470, 475 is disposed between the probe card 110 and the stiffening elements 360, 365. In an another example of the present invention, two such energy transmissive devices 470, 475 are utilized, preferably one adjacent to the tester side of the probe card 112 and one adjacent to the wafer side of the probe card 114. These energy transmissive devices 470, 475 may be embedded in the stiffeners 360, 365 as shown, but this is not necessary. In yet another example of the present invention, a plurality of energy transmissive elements 470A, 470B, 470C (FIG. 4B) are disposed between the probe card 110 and the stiffening elements 360, 365. Preferably this plurality of energy transmissive elements is arranged in a generally circular pattern. Also, the individual elements of the plurality of energy transmissive devices may be operably linked so they may be controlled together. The present invention also contemplates the use of a plurality of energy transmissive elements where the individual elements are generally triangular and arranged generally forming a circle. The individual elements may also be generally ring shaped and arranged generally as concentric rings as seen in FIG. 4B. The present invention also contemplates a combination of generally triangular and ring shaped individual energy transmissive elements.

Any suitable energy transmissive device may be utilized to practice this particular example of the present invention. For example, thermal elements such as thin film resistance control devices are particularly suited to the present invention. Thermal elements which allow for both heating and cooling such as devices which absorb or give off heat at the electrical junction of two different metals (i.e. a Peltier device) may also be used. Energy transmissive devices which do not rely on thermal energy are also contemplated by the present invention. Devices which generate a mechanical force when a voltage is applied (i.e. a piezoelectric device) may also be used.

Energy transmissive devices 470, 475 which are thermal control elements may be utilized to compensate for thermally induced motion of the probe card 110 in several ways. For example, the temperature control devices may be operated continually at the ambient temperature of the tester or at some other preselected temperature. This would tend to drive the probe card 110 to a uniform temperature regardless of the temperature of the wafer 140 and thereby prevent deformation of the probe card 110. Alternatively, the temperature control elements 470, 475 may incorporate a temperature sensing element (not shown). By sensing the temperature of the two sides 112, 114 of the probe card, the temperature control elements 470, 475 may be directed to apply or remove heat as required to compensate for any thermal gradient developing within the probe card 110. It is understood that the control methods described hereinabove while making reference to an example of the present invention incorporating two temperature control elements 470, 475 are equally applicable to alternate examples employing a single temperature control device or a plurality of control devices.

Energy transmissive devices 470, 475 according to the present invention may also be operated by monitoring conditions of the probe card 110 other than temperature. For example, a device such as a camera, laser, or other suitable means may be used to monitor the actual distance Z' (see FIG. 2A) between the probe card 110 and the wafer 140. When this distance differs from the optimal distance Z by a preselected amount, the energy transmissive devices 470, 475 are engaged to correct this deviation. A logic loop control as described in the discussion of FIG. 10 may also be used. The present invention also contemplates the use of energy transmissive devices 470, 475 similar to those shown to control the temperature of elements which hold or support the probe card 110 such as head plate 120 as seen in FIG. 1.

Referring to FIG. 5, this drawing shows an alternate example of the present invention utilizing a bi-material stiffening element 580 to compensate for thermally induced motion of the probe card 110. Although certain elements have been exaggerated for clarity, the dashed lines in the figure properly indicate the alignment of the various components. The materials used in the bi-material stiffening element preferably expand at different rates to the input of energy. For example, the upper material 582 may have a different coefficient of thermal expansion than the lower material 584 such that the two materials will react to temperature changes at different rates. Typically the layers of the bi-material stiffening element will be composed of two metals having different coefficients of thermal expansion although other materials such as ceramics and plastics may also be used. Preferably the bi-material stiffening element is located at or near the perimeter of the probe card, but other configurations are also contemplated. The materials and the thickness of the materials are chosen such that the bow created in the bi-material stiffening element 580 counteracts the expected bow of the probe card 110 for a particular application. For example, if the wafer 140 (which is typically located below the probe card 110 as shown in FIG. 2) is to be heated to a temperature greater than the ambient temperature of the tester, the bi-material stiffening element 580 would be selected such that the upper material 582 would have a greater coefficient of thermal expansion than the lower material 584. This would cause the upper material 582 to expand more rapidly than the lower material 584 giving the bi-material stiffening element 580 an upward bow to counteract the expected bow of the probe card 110 (as shown in FIG. 2A). Although not shown in FIG. 5, the present invention also contemplates the use of bi-material stiffening elements in place of the tester side stiffening element 365 as well as the use of multiple bi-material stiffening elements in the place of a single bi-material stiffening element. Additionally, the bi-material stiffening elements of the present invention may be attached to the probe card 110 by means described hereinabove for the attachment of stiffening elements to probe cards or by any other suitable method. The present invention also contemplates the use of a bi-material stiffener such that the probe card 110 is disposed between the layers of the bi-material stiffener.

FIGS. 6 and 7 illustrate variations of another example according to the present invention. The dashed lines in the figures properly indicate the alignment of the various components although certain elements have been exaggerated for clarity. This particular example of the present invention incorporates a means for allowing radial movement of the probe card 110 relative to the wafer side stiffening element 360. This radial movement means is disposed between the probe card 110 and the wafer side stiffening element 360. Specifically shown are rolling members 690 (FIG. 6) and lubricating layer 792 (FIG. 7), although other means for allowing radial motion of the probe card 110 relative to the wafer side stiffener 360 are also contemplated. The rollers 690 may be ball bearings, cylindrical bearings, or any other suitable shape. The lubricating layer 792 may be a layer of graphite or other suitable material. Alternatively, the lubricating layer 792 may be a low-friction film composed of a material such as diamond or Teflon®, or any other suitable material. This lubricating layer may be applied to the surface of the probe card 110, the surface of the stiffening element 360, 365, or both.

Although a fastening means between the probe card 110 and the wafer side stiffening element 360 is omitted from the illustration, it is understood that any suitable fastening method may be used. The wafer side stiffening element 360 may be fastened to the tester side stiffening element 365 or alternatively directly to the probe card 110 as described hereinabove. Although known fastening methods such as bolts or screws will typically allow for sufficient radial movement between the probe card 110 and the wafer side stiffening element 360, the present invention also contemplates the use of a fastening means allowing for greater radial movement such as radially oriented slots, dovetails or tracks. As shown in FIG. 6B, the wafer side stiffening element 360 may be fastened to the probe card 110 by bolts 692 which pass through slots 694 in the wafer side stiffening element 360. These bolts 692 may be fastened directly to the probe card 110 or may alternatively pass through holes (not shown) in the probe card 110 and fasten to the tester side stiffening element (not shown).

The example of the present invention illustrated in FIGS. 6 and 7 compensates for thermally induced motion of a probe card in the following manner. In the case of a probe card 110 exposed to a wafer 140 at a higher temperature than the ambient temperature of the tester, a temperature gradient begins to develop across the probe card 110. The wafer side of the probe card 114 begins to expand more rapidly than the tester side 112 of the probe card.

As the wafer side of the probe card 114 begins to expand, the rollers 690 allow for radial motion of the probe card 110 relative to the wafer side stiffening element 360. Typically only a small amount of radial motion is necessary to prevent deformation of the probe card. In some cases, movement of 10 to 20 microns is sufficient, although the present invention also contemplates embodiments allowing for greater and lesser degrees of radial motion.

Yet another example of the present invention may be described by referring to FIG. 8. In this particular example of the present invention, the distance between the wafer 140 and the probe card 110 is corrected during the testing procedure to compensate for thermally induced motion of the probe card. As previously described, once the wafer 140 is secured in the tester to the wafer chuck 150 it is moved to the effective distance Z from the probe card 110 to allow for engagement of the probes 130 with the bond pads 145. As testing proceeds, a thermal gradient in the probe card 110 may be induced by proximity to a wafer 140 at a temperature significantly different from that of the tester leading to thermally induced motion of the probe card 110 as shown in FIGS. 2A and 2B. To compensate for this motion, the present invention also contemplates a system whereby the distance Z between the probe card 110 and the wafer 140 is monitored during the testing procedure. As thermally induced motion begins the actual distance between the probe card 110 and the wafer 140 may change, this alteration is detected and the wafer 140 is returned to the optimally effective distance Z. For example, if the probe card began to sag as shown in FIG. 2A, the decrease in the actual distance Z' between the probe card 110 and the wafer 140 is detected and the table actuator 155 lowered to return the wafer 140 to the optimal effective distance Z from the probe card.

The actual distance between the probe card 110 and the wafer 140 may be monitored by any suitable means. Once such means includes monitoring the pressure exerted on the probe elements 130 by the bond pads 145. Changes in this pressure can be monitored and a signal relayed to the control system for the table actuator to order a corresponding corrective movement of the wafer 140. This is but one specific example of a means for monitoring the distance between the wafer 140 and the probe card 110. Other means for monitoring this distance such as the use of lasers, including proximity sensors, captive proximity sensors, or cameras are also contemplated by the present invention. Such sensors may be a part of the tester or alternatively may be incorporated in the probe card.

FIGS. 26-30 show diagrammatic views of an alternative method of monitoring the actual distance between the probe card 110 and the wafer 140 during the testing process. In the example illustrated in FIG. 26, a mirror 210 is attached to the probe card 110 or alternatively to a space transformer 230 (if used). A light beam 235 from a light source 200 is directed towards the mirror 210. The mirror 210 is positioned such that the light beam 235 is reflected towards a light detector 215 which detects the position of the light beam 235 and transmits this information to a positioning computer 225. Optionally, the signal from the light detector 215 may first pass through an amplifier 220 before transmission to the positioning computer 225. At initiation of the testing process when the probe card 110 is planar, the position of the light beam 235 is detected and noted as the zero position. As the testing process proceeds, thermal gradients may develop across the probe card 110 causing thermally induced motion of the probe card 110 as previously described. As the position of the probe card 110 changes from this thermally induced motion, the angle at which the light beam 235 strikes the mirror 210 also changes. This causes the reflected light beam 235 to strike the light detector 215 at a different position than the initial zero position. When this information is transmitted to the positioning computer 225, the change in the light beam 235 position causes the positioning computer 225 to generate a control signal that is transmitted to the tester. The tester then adjusts the Z position (vertical as shown) of the wafer 140 being tested to compensate for the thermally induced deflection of the probe card 110. Additional thermally induced motion of the probe card 110 is monitored by the positioning computer 225 continually during the testing procedure.

FIG. 26 shows but one example of a method of monitoring the actual distance between a probe card 110 and a wafer 140. The specific nature of the light source 200 used may vary. One such suitable light source 200 is a diode laser, although other light sources may also be used. The detector used 215 in a particular application will vary according to the light source 200 used. For example, if the light source 200 used is a laser, one suitable detector 215 would be a diode array detector such as the AXUV-20EL manufactured by International Radio Detectors. In this particular example the positioning computer 225, amplifier 220, light detector 215 and light source 200 are shown as individual components separate from the tester. Alternatively, these elements may be combined with one another (e.g., a positioning computer 225 incorporating an amplifier 220) or incorporated into the tester itself.

In another example of a method to detect thermally induced motion in a probe card 110 shown in FIG. 27, the light source 200 is attached to the space transformer 230 of the probe card 110. Alternatively, the light source 200 may be attached to the probe card 110. The light source 200 generates a light beam 235 that strikes the light detector 215. As in the example describe in FIG. 26, when the testing process begins the probe card 110 is initially planar and the position at which the light beam 235 strikes the detector 215 is noted as the zero position by the positioning computer 225. As the testing process begins and thermally induced motion of the probe card 110 develops, the location at which the light beam 235 strikes the detector 215 changes. In response to this change the positioning computer 225 generates a control signal causing the tester to adjust the Z position (vertical as shown) of the wafer 140 to compensate for the change in the probe card's 110 position.

FIG. 28 shows another example of a method of monitoring the distance between a probe card 110 and the wafer 140 being tested. This example is similar to that described in FIG. 27 but incorporates two concave mirrors 240 located between the light source 200 and the detector 215. Additionally, this example includes a calibration device 245 to adjust the position of the detector 215. The calibration device 245 allows the position of the detector 215 to be adjusted so that the light beam 235 strikes the detector 215 at a predetermined location at the beginning of the testing procedure. This allows the system to compensate for variations in the initial position of a particular probe card within a tester and for variations in the attachment location of the light source to a particular probe card. The calibration device 245 may also be used to adjust the position of the detector 215 during the testing process to compensate for thermally induced motion of the probe card 110 which occurs during testing. The calibration device 245 shown in FIG. 28 may also be adapted to use in other examples of the monitoring method such as that shown in FIG. 26.

The calibration device 245 may also be used to compensate for other variations. For example, the light detector 215 may consist of a series of diodes whose output response to a particular light source is not necessarily equivalent. That is, the signal from the light beam 235 striking a particular detector element 216 is not necessarily precisely the same as that striking an adjacent detector element 217. By moving the light detector 215 in the Z axis direction (vertical as shown), each individual element of the light detector 215 may be subjected to the same light beam intensity. At the same time, the Z position of the detector 215 may be precisely measured by using an encoder on the Z motion drive for the detector 215, or some other means of measuring the position of the detector 215 in response to the Z drive. This allows the response of the light detector 215 to actual Z axis motion of the probe card 110 to be precisely known. Additionally, the output of the light source 200 may drift over time. To allow the system to differentiate between output drift and position changes of the probe card 110, periodically the system may stop compensating for Z axis motion of the probe card 110 and reenter calibration mode to reacquire the detector response to the light source 200. Optionally, it may be advantageous to insert a low pass filter between the amplifier 220 and the positioning computer 225 to prevent high frequency noise from entering the system.

The use of cylindrical mirrors 240 between the light source 200 and the light detector 215 also allows the system to compensate for variations in the light source's 200 position. As seen in a top view in FIG. 28A, the light beam 235 first strikes the cylindrical mirrors 240 prior to striking the light detector 215. The concave nature of the mirrors 240 compensates for variations in the initial position of the light source 200 by redirecting the light beam 235 towards the light detector 215. The calibration device 245 and the cylindrical mirrors 240 shown in FIG. 28 need not be used together and the present invention also contemplates monitoring methods which incorporate only one of these features.

Another example of a method of monitoring the actual distance between a probe card 110 and the wafer 140 being tested is shown in FIG. 29. In this example, a lens 246 is located between the light source 200 and the light detector 215. The lens 246 is shown as attached the probe card 110, but alternatively the lens 246 may also be attached to a space transformer 230 (if used). In this particular example, the light source 200 produces a light beam 235 that passes through the lens 246. The lens 246 refracts the light beam 235, which then strikes the light detector 215. The position of the light beam 235 is detected and noted as the zero position at initiation of the testing process when the probe card 110 is planar. As the testing process proceeds thermal gradients cause thermally induced motion of the probe card 110. As the position of the probe card 110 changes from this thermally induced motion, the location at which the light beam 235 strikes the lens 246 also changes. This alters the angle to which the light beam 235 is bent by the lens 246 and causes the refracted light beam 235 to strike the light detector 215 at a different position than the initial zero position. When this information is transmitted to a positioning computer 225, the change in the light beam 235 position causes the positioning computer 225 to generate a control signal, which is transmitted to the tester. The tester then adjusts the Z position (vertical as shown) of the wafer 140 being tested to compensate for the thermally induced deflection of the probe card 110.

Another example of a distance monitoring method utilizing a lens 246 is shown in FIG. 30. In this example, the light source 200 is located on a space transformer 230 attached to the probe card 110. Alternatively, the light source 200 may be attached to the probe card 110 itself. The light source 200 generates a light beam 235, which is refracted by a lens 246 before striking a light detector 215. This particular example also shows the calibration device 245 previously described.

Preferably the actual distance Z' between the wafer 140 and the probe card 110 is monitored by a computer using a logic loop similar to that shown in FIG. 10. After the user inputs the desired distance Z between the wafer 140 and the probe card 110 to be maintained 10, indicates the maximum allowable deviation from this distance 20, and any other information specific to the particular testing procedure, the testing procedure begins. The computer begins by detecting the actual distance Z' between the wafer 140 and the probe card 110 at the step labeled 30 using a suitable detecting means as previously described. The computer then compares the actual distance Z' to the desired distance Z at the step labeled 40. If the absolute magnitude of the difference between Z and Z' is greater than the maximum allowable deviation as set at box 20, then the computer applies the appropriate corrective action 80 before returning to box 30 to begin the loop again. If the absolute magnitude of the difference between Z and Z' is less than the maximum allowable deviation as set at box 20, then the computer returns to the beginning of the logic loop 30. The corrective action taken at box 80 will of course depend on which particular corrective device or combination of devices as previously described are used with a particular probe card. Preferably where more than one device according to the present invention is used in a single probe card, a single computer will control all such devices, although this is not necessary. Preferably the control computer is a part of the tester although alternatively it may be incorporated on the probe card.

Control of the actual distance between the probe card 110 and the wafer 140 as previously described also compensates for probe card deformation other than thermally induced deformation. As the probe elements 130 are generally located near the center of the probe card 110 as seen in FIG. 1, the engagement of the probe elements 130 with the bond pads 145 imparts an upward (as shown) force on the center of the probe card 110. This force may lead to a deformation of the probe card 110 characterized by a bow near the center of the card. The control systems previously described may also correct for this type of probe card deformation by monitoring and correcting the actual distance between the probe card 110 and the wafer 140. These methods may also be used to compensate for deflection caused by force exerted on a probe card when a probe card contacts travel stops (not shown) designed to prevent damage to a wafer by a tester accidentally moving the wafer too close to the probe card.

An alternative method of maintaining the planarity of a probe card according to the present invention is shown in FIGS. 13-25. In this method planarity is maintained using at least one layer of a shape memory alloy (SMA) located on or in the probe card. A shape memory alloy is a member of a group of alloys that demonstrate the ability to return to a previously defined shape or size when subjected to the appropriate thermal conditions. Generally these alloys may be deformed at some lower temperature, and upon exposure to some higher temperature, return to their shape prior to deformation. SMAs undergo a phase transformation in their crystal structure when cooled from the stronger, higher temperature form (austenite) to the weaker, lower temperature form (martensite). When an SMA is in its martensitic phase it is easily deformed. When the deformed SMA is heated through its transformation temperature, it reverts to austenite and recovers its previous shape. Preferably the SMA used will be one of several suitable Nickel-Titanium alloys (NiTi). NiTi alloys exhibit excellent strength, thermal stability and corrosion resistance. Other SMAs such as copper-based alloys may also be used to practice the present invention.

As seen in the example shown in FIG. 13A-B, a plurality of strips 255 of an SMA are incorporated into the surface of a probe card 250. The planarity of the probe card 250 in this particular example is monitored by using a plurality of strain gauges 260 located on the surface of the probe card 250 as seen in cross-sectional view 13B. These strain gauges 260 are in electrical contact with a computer (not shown) which monitors the position of the probe card 250. When the strain gauges 260 detect a predetermined strain at the surface of the probe card 250 indicating deformation of the card, the monitoring computer issues a command to heat the SMA strips 255 located where the deflection is occurring. When the SMA strips 255 are heated, they transform from the martensitic phase to the austenitic phase and return to their memory shape (i.e., planar). The return of the SMA strips 255 to a planar state exerts a force on the probe card 250 to also return to a planar state.

The example shown in FIGS. 13A-B is but one example of using SMA layers to control planarity. Although this example shows the use of SMAs to maintain planarity in a probe card, the present invention also contemplates the use of SMAs in any PCB or built up structure where maintaining planarity of the structure is important. Also, although this example shows the use of strain gauges to monitor the planarity of the probe card, other methods of monitoring planarity such as optical methods previously described may also be used.

The particular arrangement of SMA layers 255 and strain gauges 260 shown in FIGS. 13A-B is but one potential arrangement. Other, non-limiting suitable arrangements are shown in FIGS. 14-25. FIGS. 14A-B show a probe card 250 having SMA strips 255 imbedded in both the upper and lower surfaces (as shown in FIG. 14B) of the probe card 250. FIGS. 14A-B also show the use of strain gauges 260 located on both the upper and lower surfaces of the probe card 250 to monitor planarity. FIGS. 15A-B show an arrangement similar to than shown in FIGS. 14A-B. In this example, however, the SMA strips 255 near the upper surface (as shown in FIG. 15B) of the probe card 250 are arranged to be generally perpendicular to the SMA strips 255 near the lower surface of the probe card 250. Alternatively, both layers of SMA strips 255 could be arranged near the same surface of the probe card 250 as shown in FIGS. 16A-B. The SMA strips 255 need not be linear. In the example arrangement shown in FIGS. 17A-B, a probe card 250 has a plurality of SMA strips 255 embedded near the center of the structure (as shown in FIG. 17B) and a plurality of concentric circular SMA strips 255 embedded near the upper surface of the structure.

The SMA strips need not be embedded in the probe card structure. As seen in FIG. 18A-B, a probe card 250 may have a plurality of SMA strips 255 embedded in one side and a plurality of SMA strips 255 fixed to the opposite surface. This example also illustrates that the different layers of SMA strips 255 may be disposed at some angle other than parallel or perpendicular as shown in the previous configurations. FIGS. 19A-B show an example of the present invention of a probe card 250 having no embedded SMA strips. Instead, in this example SMA strips 255 are fixed to the upper and lower surfaces (as shown in FIG. 19B) of the probe card 250. This example also shows a plurality of fastener holes 265 passing through the SMA strips 255 and the probe card 250. These fastener holes 265 may be used to secure other devices to the probe card 250 such as a space transformer.

The SMA strips may be of varying thickness as desired. FIGS. 20A-B show a probe card 250 having a plurality of SMA strips 255 embedded in the card 250. The strips in this particular example vary in thickness across their length. Some of the strips 255A are thicker near the end of their length while others 255B are thicker near the center of their length. As seen in FIGS. 21A-B, SMA strips 255 may be embedded in a probe card 250 so that alternating sections of a particular strip are near the upper and lower surfaces of the probe card 250.

The strain gauges used to monitor planarity of the probe card need not be attached to the surface of the card. As seen in FIGS. 22A-B, strain gauges 260 may also be embedded in the probe card 250. Embedded strain gauges may also be used with any of the configurations of SMA strips previously described. For example, embedded strain gauges 260 may be used with a circular configuration of SMA strips 255 as shown in FIGS. 23A-B. FIGS. 24A-25 show other examples of circular arrangements of SMA material 255 which may be used to practice the present invention.

FIGS. 11 and 12 show diagrammatic views of one example of a prober and a tester usable in connection with the present invention. In this particular embodiment, prober 100 is physically separate from tester 180. They are connected by one or more cables, such as communication cable 180a and 180b as illustrated. Cable 180a connects to the test head of the prober that is connected to probe card 110 by electrical connections 110a. Probe card as probes 130 as previously described. In this embodiment, wafers, such as wafer 140 on stage 150, may be placed from the wafer boat 170 by robotic arm 160. Tester 180 generates test data that is sent to the tester 190 via communications cable 180a and may receive response data from the tester via communications cable 180a. The test head 190 receives data from the test head 180 and passes the test data through the probe card 110 to the wafer. Data from the wafer is received through the probe card and sent to the tester. The prober houses, in the preferred embodiment, the wafer boat stager robotic arm as illustrated. The tester may control the prober in a variety of ways, including communication cable 180b. The wafer boat 170 stores wafers to be tested or that have been tested. The stage supports the wafer being tested, typically moving it vertically and horizontally. Typically, the stage is also capable of being tilted and rotated and is capable of moving the wafer being tested against probes 130. This may compromise a wafer chuck and table actuator as previously described. The robotic arm 160 moves wafers between stage 150 and the wafer boat 170.

The tester is typically a computer, and the prober typically also includes a computer or at least a computer-like control circuitry (e.g. a microprocessor or microcontroller or microcode). Test head 190 may similarly include computer or computer-like control circuitry. In the preferred embodiment the computer which carries out the acts illustrated in FIG. 10 is preferably located in the prober. This may be an existing computer or computer-like control circuitry already in the prober or alternatively a new computer added to the prober for this purpose. Alternatively, the computer may be located in the tester 180, in which case feedback signals regarding the position of the wafer with respect to the probe card would be typically communicated to the tester via communication cable 180b. The control signals removing the stage are likewise communicated via that cable.

As yet another alternative, the computer may be located in the test head 190 the suitable communication means between the prober 100 and test head 190. Such communication means may be via wired connections, RF transmissions light or other energy beam transmissions and the like.

Yet another alternative, a separate computer distinct from the tester, test head and prober, could be used and connected electrically to the prober for this purpose.

As yet another alternative, a computer, microprocessor, microcontroller and the like may actually be made part of the probe card 110 for the appropriate input and output connections to facilitate the running of steps of FIG. 10. For example, in this way each probe card may have as a part of or imbedded therein its own dedicated and/or customized algorithm acts and/or parameters such as those provided for in connection with FIG. 10.

Probe cards need not be limited to a single device described herein to compensate for thermally induced motion according to the present invention. Indeed, the present invention contemplates the combination two or more of the devices previously described in a single probe card. The example shown in FIG. 9 employs a tester side energy transmissive device 470, a wafer side energy transmissive device 475, a lubricating layer 792 to allow for radial motion of the probe card 110, and a bi-material stiffening element 580. Other combinations using two or more of the previously described devices to compensate for thermally induced motion in probe cards are also contemplated. Preferably any probe card incorporating two or more of the above-described devices would also include a control means capable of controlling all of the devices incorporated, but the present invention also contemplates utilizing individual control means or no control means in any particular probe card.

While the invention has been illustrated and described in detail in the drawings and foregoing description, the same is to be considered as illustrative and not restrictive in character, it being understood that only the preferred embodiment have been shown and described and that all changes and modifications that come within the spirit of the invention are desired to be protected. The articles "a", "an", "said" and "the" are not limited to a singular element, and include one or more such element.

CLAIMS

What is claimed is:

1. An apparatus comprising:

a probe card for testing a die on a wafer;

an energy transmissive element located adjacent to said probe card at a portion of said probe card;

wherein said energy transmissive element utilizes energy transmitted to selectively deflect a portion of said probe card to selectively control the geometric planarity of said probe card.

2. The apparatus of claim 1 wherein said energy transmissive element is located generally along a perimeter of said probe card.

3. The apparatus of claim 2 wherein said energy transmissive element is a thermal element employing thermal energy to selectively deflect a portion of said probe card.

4. The apparatus of claim 3 and further including a temperature sensor located near said energy transmissive element for monitoring temperature corresponding to deflection of said probe card.

5. The apparatus of claim 4 and further including a stiffening element attached to a face of said probe card and adapted to provide structural resistance to planarity deflection of said probe card.

6. The apparatus of claim 5 and further comprising means for facilitating radial expansion/contraction of said probe card with respect to said stiffening element.

7. The apparatus of claim 6 and further including a multi-layer element having a first layer and a second layer, said first layer and said second layer having different rates of expansion per unit of energy, said multi-layer element being attached to said probe card, wherein exposing said multi-layer element to energy causes said multi-layer element to selectively impart deflective forces to a portion of said probe card.

8. The apparatus of claim 7 wherein said multi-layer element includes two layers of different metals/alloys having a different coefficient of thermal expansion than the other.

9. The apparatus of claim 8 wherein said multi-layer element is located generally along a perimeter of said probe card.

10. The apparatus of claim 1 wherein said energy transmissive element is a thermal element employing thermal energy to selectively deflect a portion of said probe card.

11. The apparatus of claim 1 and further including a temperature sensor located near said energy transmissive element for monitoring temperature corresponding to deflection of said probe card.

12. The apparatus of claim 1 and further including a stiffening element attached to a face of said probe card and adapted to provide structural resistance to planarity deflection of said probe card.

13. The apparatus of claim 1 and further comprising means for facilitating radial expansion/contraction of said probe card with respect to said stiffening element.

14. The apparatus of claim 1 and further including a multi-layer element having a first layer and a second layer, said first layer and said second layer having different rates of expansion per unit of energy, said multi-layer element being attached to said probe card, wherein exposing said multi-layer element to energy causes said multi-layer element to selectively impart deflective forces to a portion of said probe card.

15. The apparatus of claim 14 wherein said multi-layer element includes two layers of different metals/alloys having a different coefficient of thermal expansion than the other.

16. The apparatus of claim 15 wherein said multi-layer element is located generally along a perimeter of said probe card.

17. An apparatus comprising:

a probe card for testing a die on a wafer;

a multi-layer element having a first layer and a second layer, said first layer and said second layer having different rates of expansion per unit of energy, said multi-layer element being attached to said probe card, wherein exposing said multi-layer element to energy causes said multi-layer element to selectively impart deflective forces to a portion of said probe card.

18. The apparatus of claim 17 wherein said multi-layer element includes two layers of different metals/alloys having a different coefficient of thermal expansion than the other.

19. The apparatus of claim 17 wherein said multi-layer element is located generally along a perimeter of said probe card.

20. The apparatus of claim 19 wherein said multi-layer element includes two layers of different metals/alloys having a different coefficient of thermal expansion than the other.

21. The apparatus of claim 19 and further comprising a stiffening element and means for facilitating radial expansion/contraction of said probe card with respect to said stiffening element.

22. The apparatus of claim 17 and further comprising a stiffening element and means for facilitating radial expansion/contraction of said probe card with respect to said stiffening element.

23. An apparatus comprising:

a probe card for testing a die on a wafer;

a stiffening element attached to a face of said probe card and adapted to provide structural resistance to planarity deflection of said probe card; and,

means for facilitating radial expansion/contraction of said probe card with respect to said stiffening element.

24. The apparatus of claim 23 wherein said means for facilitating radial expansion/contraction comprises rolling members between said probe card and said stiffening element.

25. The apparatus of claim 23 wherein said means for facilitating radial expansion/contraction comprises radially oriented slot connections between said probe card and said stiffening element.

26. The apparatus of claim 23 wherein said means for facilitating radial expansion/contraction comprises a lubrication layer between said probe card and said stiffening element.

27. A method for adjusting geometric planarity of a probe card, said method comprising:

placing a probe card in a prober;

measuring a first distance from a know position to a position of said probe card;

comparing via microprocessor means said first distance to a second distance to determine a variance therebetween; and,

when said microprocessor determines said variance exceeds a determined value, electrically signaling means for transmitting energy to said probe card to selectively deflect said probe card to control the geometric planarity of said probe card.

28. The method of claim 27 wherein said comparing and signaling are done repetitively until said variance does not exceed said determined value.

29. The method of claim 28 wherein said act of measuring is with an optical sensor.

30. The method of claim 29 wherein said microprocessor is in a test head on said prober.

31. The method of claim 29 wherein said microprocessor is in a tester that is physically separate from said prober and is connected thereto by means for data communication.

32. The method of claim 29 wherein said means for transmitting energy transmits thermal energy to said probe card, and wherein said probe card comprises a bi-metallic element connected thereto to impart deflection.

33. The method of claim 27 wherein said act of measuring is with an optical sensor.

34. The method of claim 27 wherein said microprocessor is in a test head on said prober.

35. The method of claim 27 wherein said microprocessor is in a tester that is physically separate from said prober and is connected thereto by means for data communication.

36. The method of claim 27 wherein said means for transmitting energy transmits thermal energy to said probe card, and wherein said probe card comprises a bi-metallic element connected thereto to impart deflection.

37. A system for adjusting geometric planarity of a probe card, comprising:

a prober for receiving a probe card;

means for measuring a distance indicating a position of said probe card;

computer means for comparing said first distance to a second distance to determine a variance therebetween; and,

means for electrically signaling in response to said variance exceeding a value, said means for signally transmitting a signal to activate means for transmitting energy to said probe card to selectively deflect said probe card to control the geometric planarity of said probe card.

38. The system of claim 37 comprising an energy transmissive element which is a thermal element employing thermal energy to selectively deflect a portion of said probe card.

39. The system of claim 37 and further including a temperature sensor for monitoring temperature corresponding to deflection of said probe card.

40. The system of claim 37 and further including a stiffening element attached to a face of said probe card and adapted to provide structural resistance to planarity deflection of said probe card.

41. The system of claim 37 and further comprising means for facilitating radial expansion/contraction of said probe card with respect to a stiffening element.

42. The system of claim 37 and further including a multi-layer element having a first layer and a second layer, said first layer and said second layer having different rates of expansion per unit of energy, said multi-layer element being attached to said probe card, wherein exposing said multi-layer element to energy causes said multi-layer element to selectively impart deflective forces to a portion of said probe card.

43. An apparatus comprising:

a probe card for testing die on a wafer;

a shape memory alloy element connected to said probe card;

wherein said shape memory alloy utilizes thermal energy to deflect a portion of said probe card to control the geometric shape of said probe card.

44. The apparatus of claim 43 wherein said shape memory alloy element is located at least partially generally along a surface of said probe card.

45. The apparatus of claim 43 wherein said shape memory alloy element comprises and alloy of nickel and titanium.

46. The apparatus of claim 43 and further including at least one strain sensor located near said shape memory alloy element for monitoring strain corresponding to deflection of said probe card.

47. An apparatus comprising:

a probe card for testing a die on a wafer; and,

at least one strain sensor on said probe card for monitoring strain corresponding to deflection of said probe card.

48. The apparatus of claim 47 and further comprising a first shape memory alloy element on said probe card.

49. The apparatus of claim 48 and further including at least one strain sensor located near and oriented generally parallel to said first shape memory alloy element for monitoring strain corresponding to deflection of said probe card.

50. The apparatus of claim 47 wherein said strain sensor is oriented generally radially outward from a center portion of said probe card.

51. The apparatus of claim 47 wherein said strain sensor is oriented generally parallel with a peripheral edge of said probe card.

52. An apparatus comprising:

a probe card for testing a die on a wafer;

a prober for receiving said probe card for said testing;

an optical element on said probe card for directing a light beam hitting said optical element;

a light beam emitter for hitting said optical element on said probe card; and,

a light beam receiver for receiving said light beam from said optical element to measure deflection of said probe card.

53. The apparatus of claim 52 wherein said optical element comprises a lens.

54. The apparatus of claim 52 wherein said optical element comprises a mirror.

55. The apparatus of claim 54 and further comprising a pair of mirrors having facing cylindrical surfaces in said prober and through which said light beam is deflected.

56. The apparatus of claim 54 and further comprising computer processor means for computing a first position and a second deflected position of said probe card from input to said light beam receiver.

57. An apparatus comprising:

a probe card for testing a die on a wafer;

a prober for receiving said probe card for testing;

a light beam emitter on said probe card for producing a light beam; and

a light beam receiver for receiving said light beam from said light beam emitter to measure deflection of said probe card.

58. The apparatus of claim 57 and further comprising a pair of mirrors having facing cylindrical surfaces in said prober and through which said light beam is deflected.

59. The apparatus of claim 57 and further comprising a computer processor means for computing a first position and a second deflected position of said probe card from input to said light beam receiver.

60. A method of controlling the distance between a probe card and a wafer being tested in a prober, comprising:

providing a probe card for testing a plurality of die on a wafer;

providing a prober for receiving said probe card for testing;

providing a wafer on a chuck in said prober wherein said wafer is positioned for contact with said probe card;

providing a sensing system for measuring the distance between said probe card and said wafer; and,

adjusting said distance in response to changes in the distance reported by said sensing system.

61. The method of claim 60 wherein said measuring and adjusting are done repeatedly.

62. A method for controlling the distance between a probe card and a wafer in a prober, comprising:

providing a probe card for testing a plurality of die on a wafer;

providing a prober for receiving said probe card for testing;

providing a wafer on a chuck in said prober;

measuring a first distance between said probe card and said wafer;

comparing via microprocessor means said first distance to a second distance to determine a variance therebetween; and,

when said microprocessor determines said variance exceeds a determined value, adjusting the distance between said probe card and said wafer.

63. The method of claim 62 wherein said comparing and adjusting is done repetitively until said variance does not exceed a determined value.

64. An apparatus comprising:

a probe card for testing a plurality of die on a wafer;

a prober for receiving said probe card for testing;

an radiative source for transmitting a signal reporting information proportional to the position of the probe card; and,

an radiative receiver for receiving said information.

65. The apparatus of claim 64 wherein said radiative source is attached to said probe card.

66. The apparatus of claim 64 wherein said radiative source is a laser.

67. A probe card for testing a plurality of die on a wafer having an radiative source for reporting deformation of said probe card to an external sensing system.

68. The probe card of claim 67 wherein said radiative source is a laser.

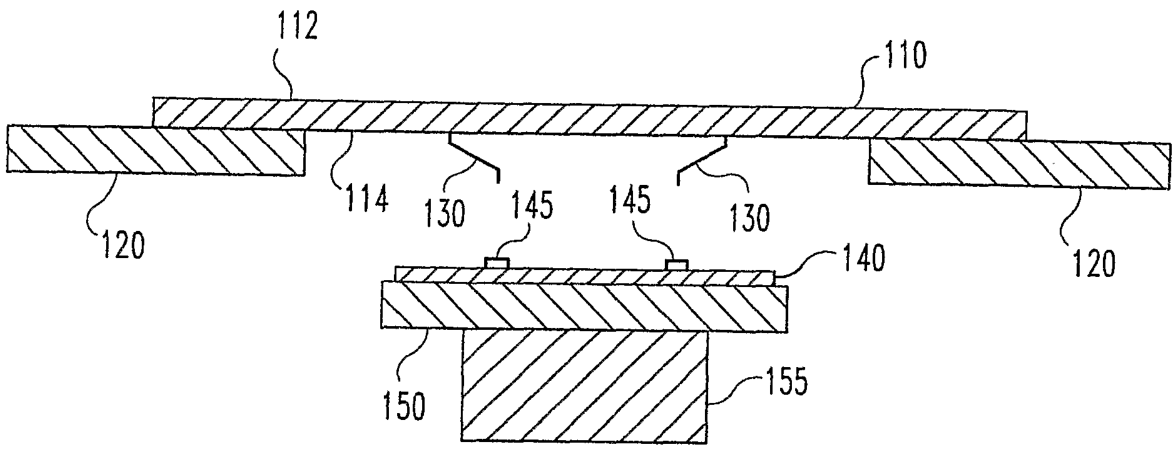


Fig. 1
(PRIOR ART)

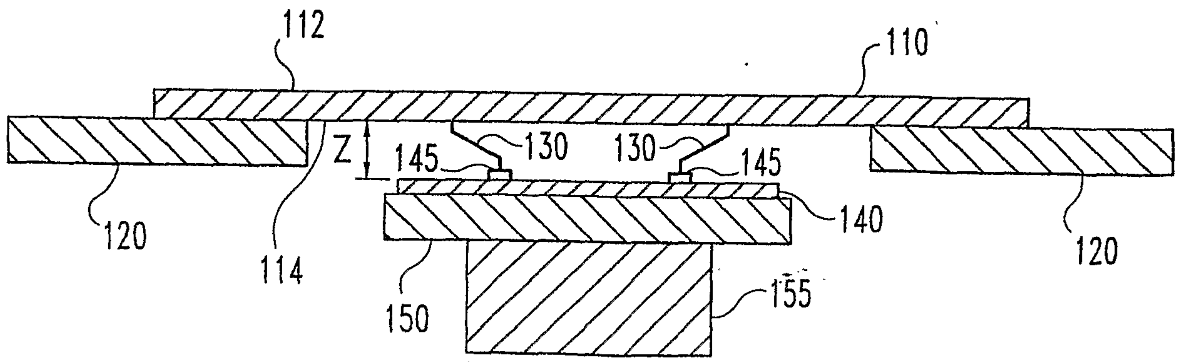


Fig. 2
(PRIOR ART)

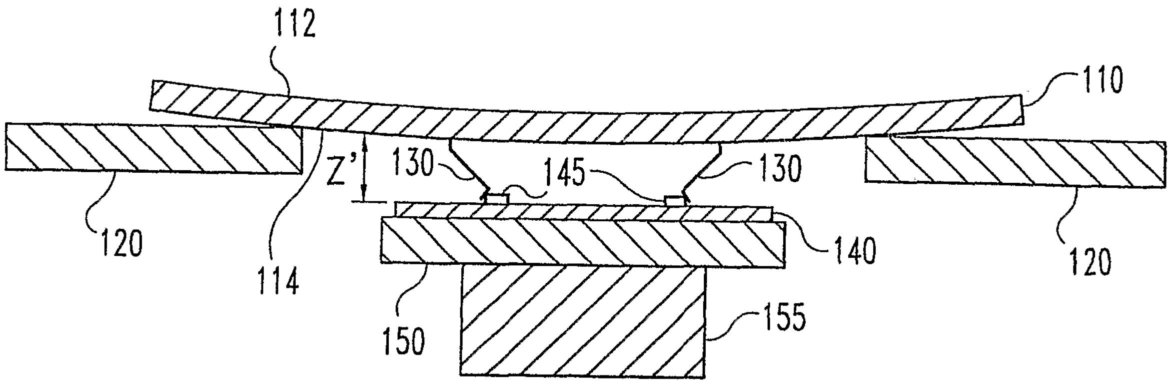


Fig. 2A
(PRIOR ART)

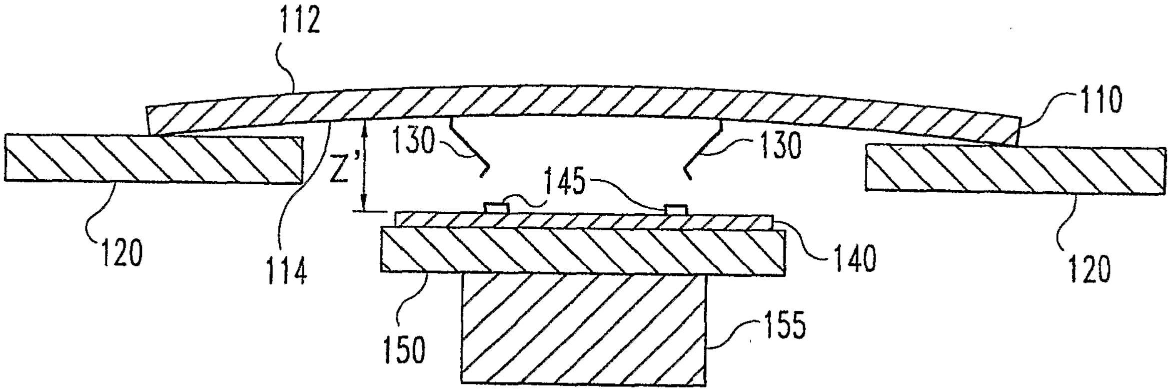


Fig. 2B
(PRIOR ART)

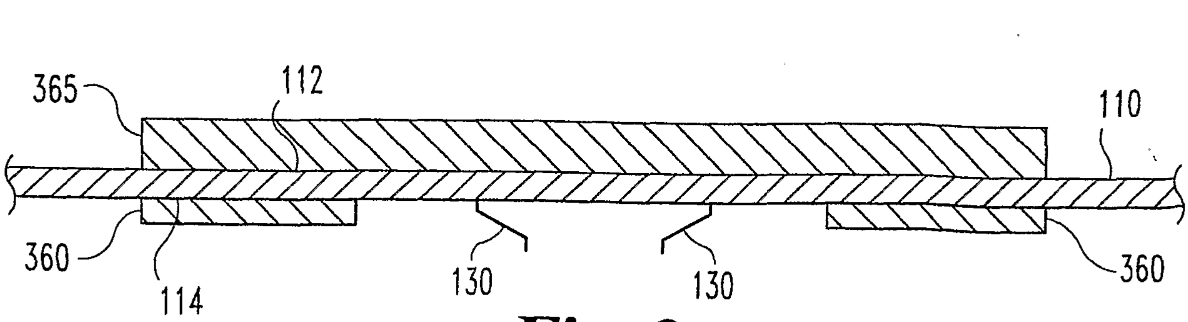


Fig. 3
(PRIOR ART)

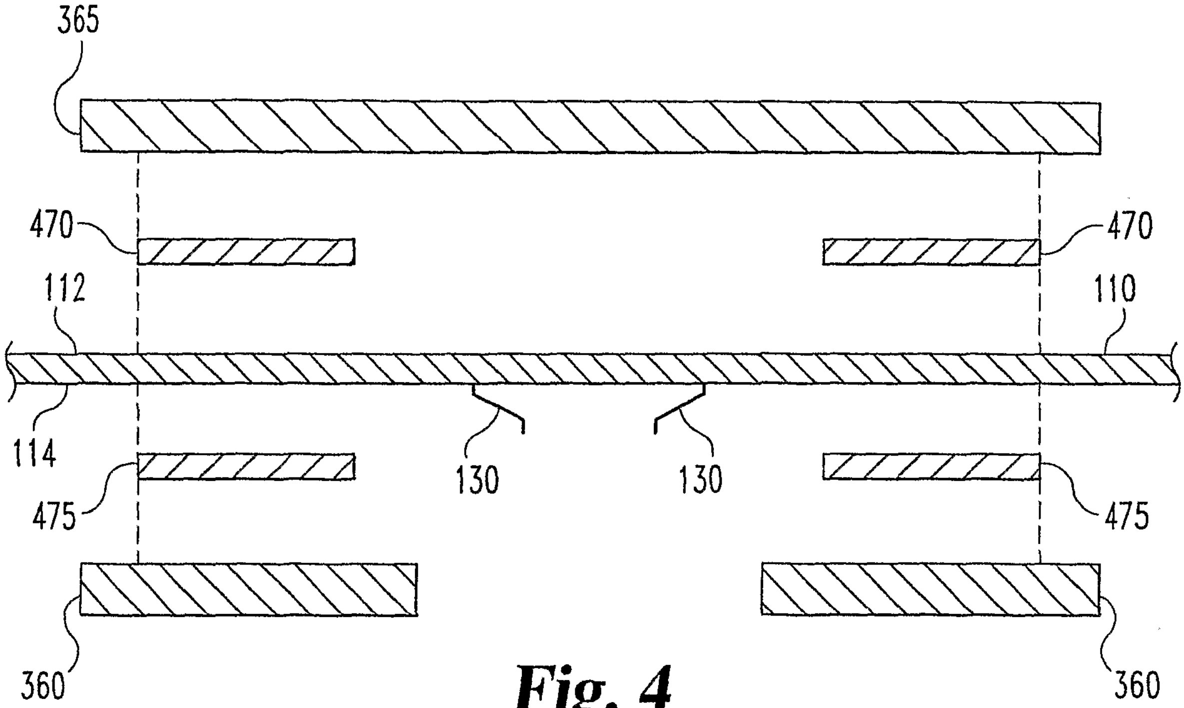


Fig. 4

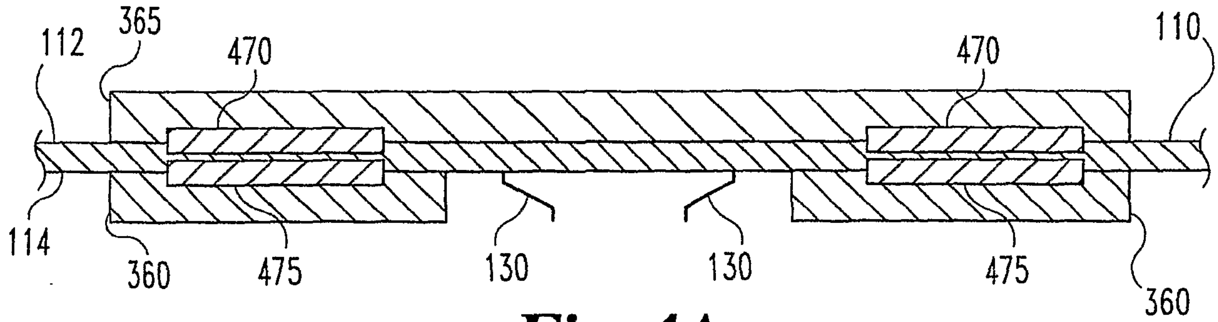


Fig. 4A

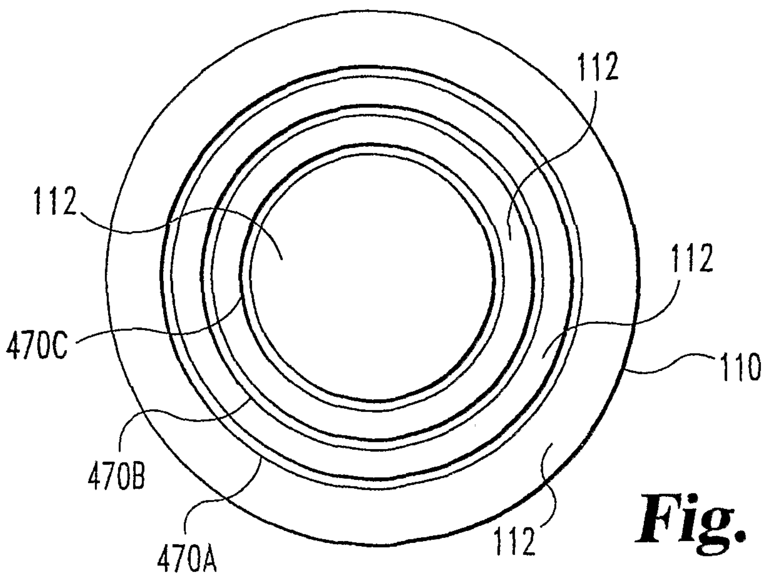


Fig. 4B

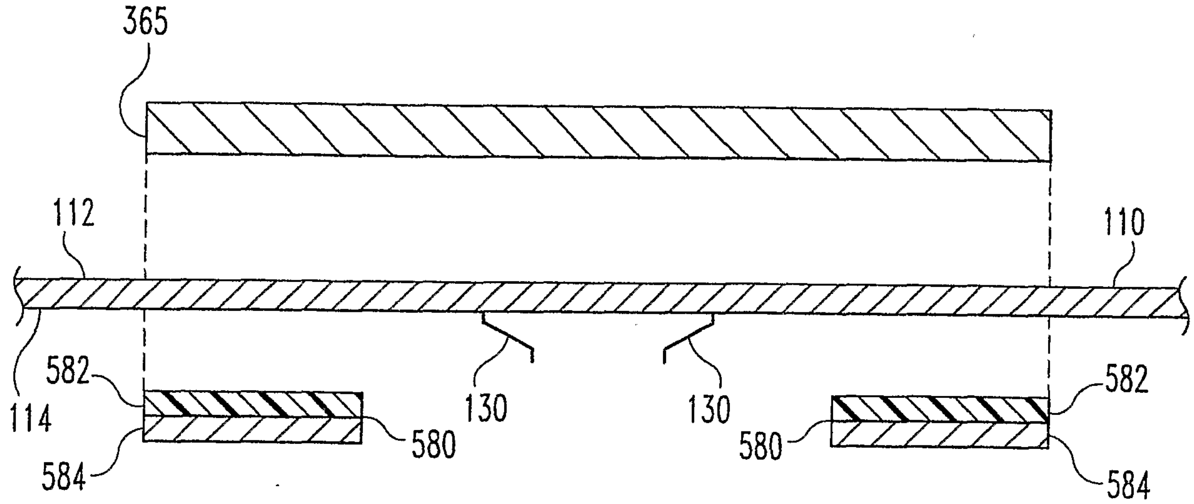

365
112
110
114
582
584
580
130
130
580
582
584

Fig. 5

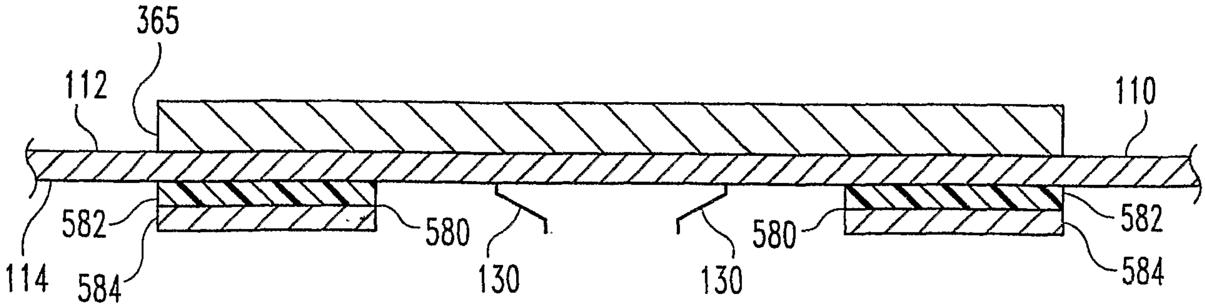

365
112
110
582
114
584
580
130
130
580
582
584

Fig. 5A

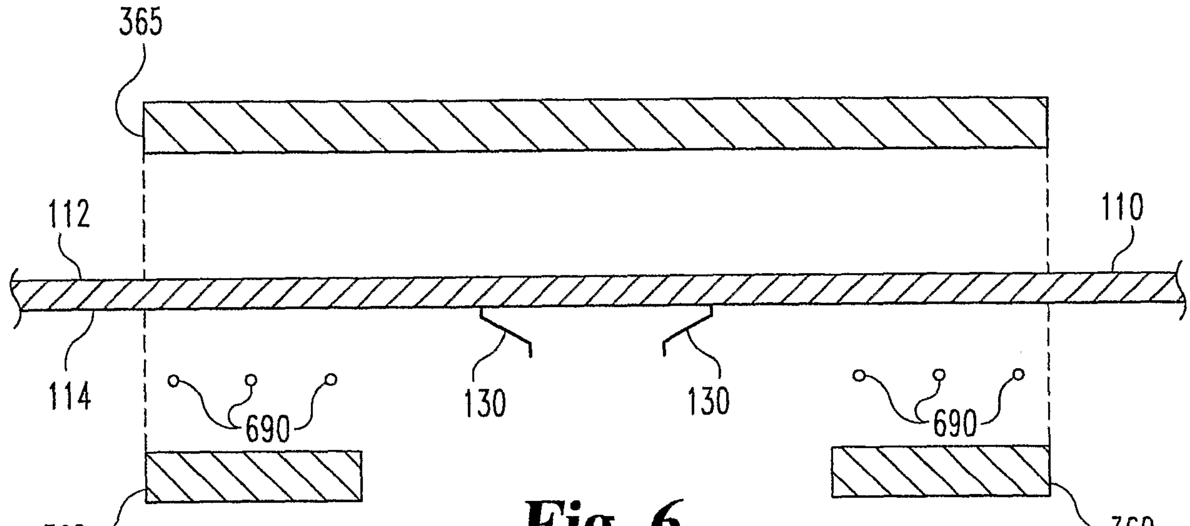

365
112
110
114
130
130
690
690
360
360

Fig. 6

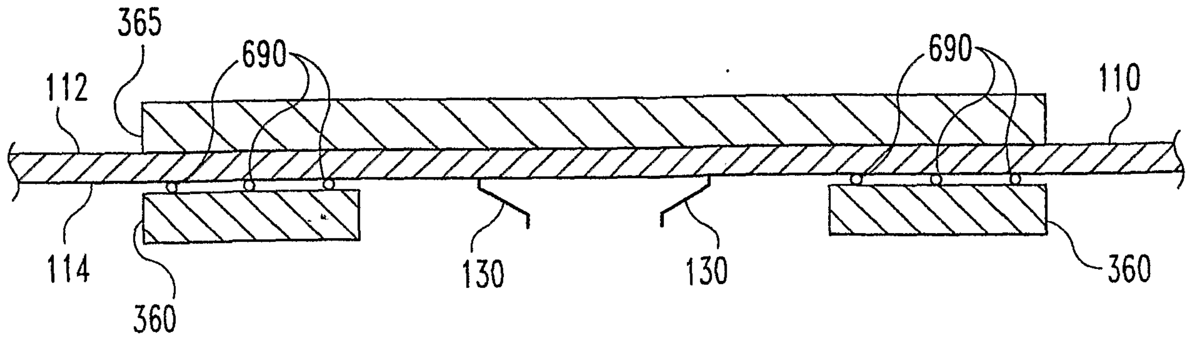

365
690
690
112
110
114
360
130
130
360

Fig. 6A

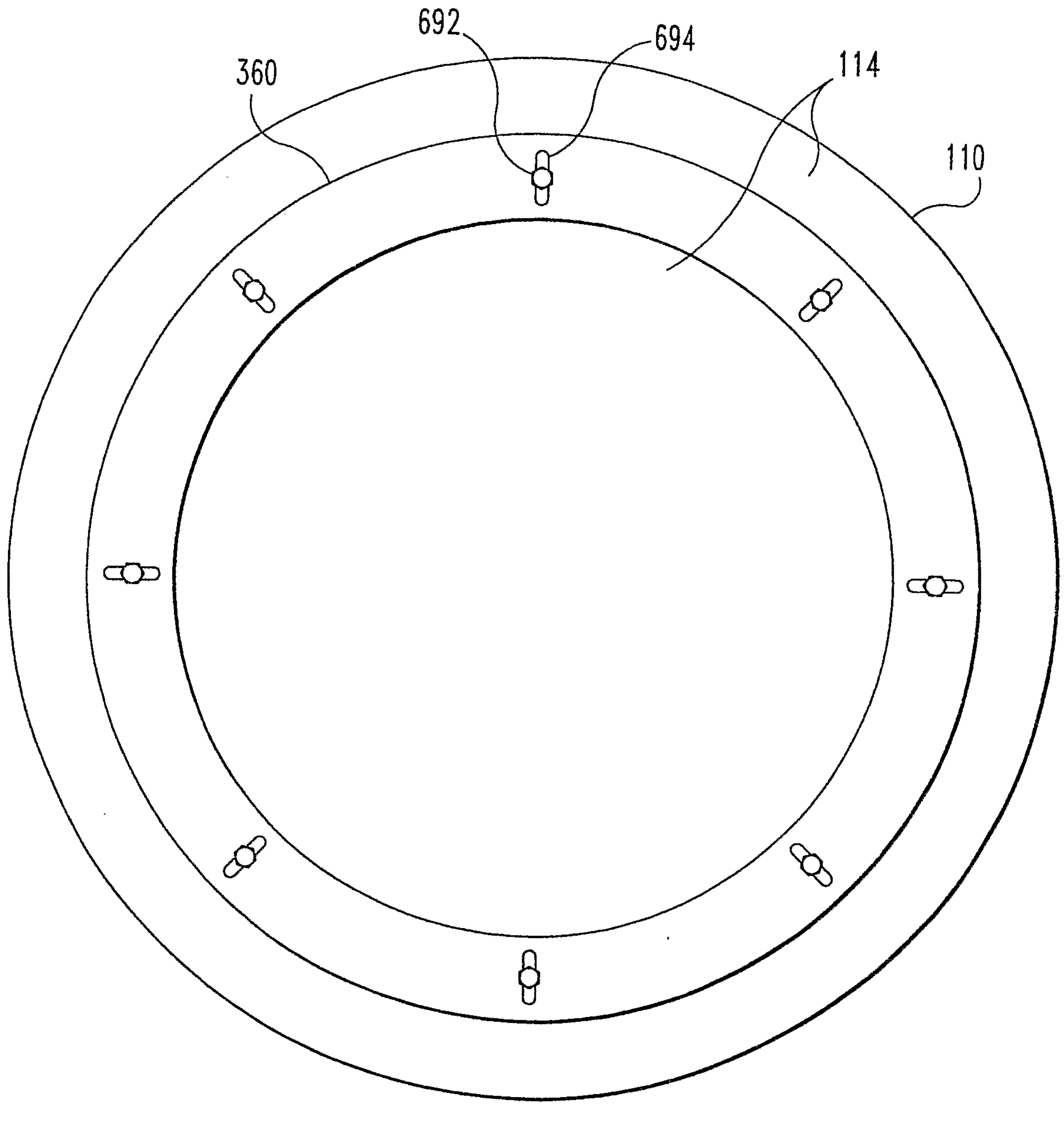


Fig. 6B

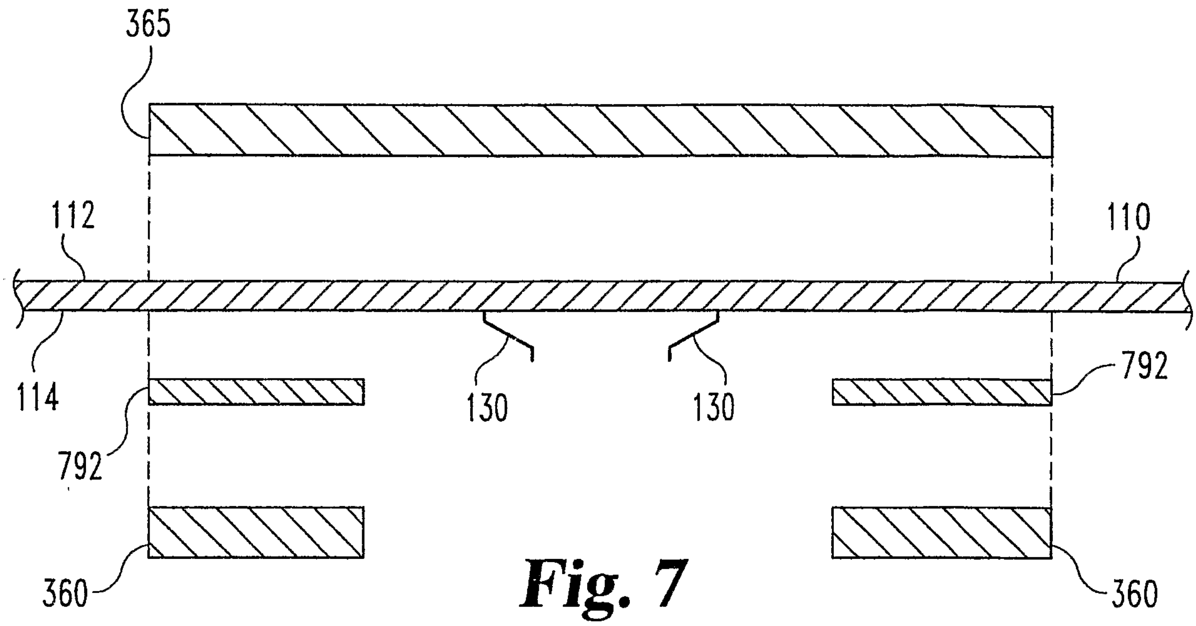

365
112
110
114
130
130
792
792
360
360

Fig. 7

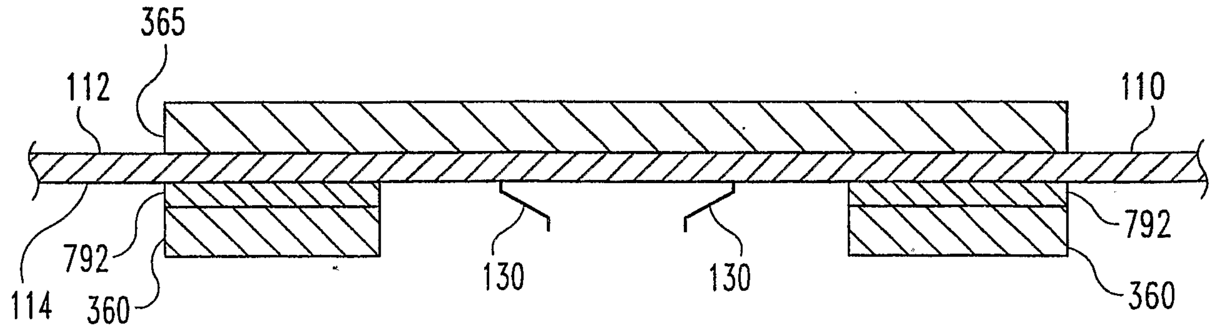

365
112
110
114
792
360
130
130
792
360

Fig. 7A

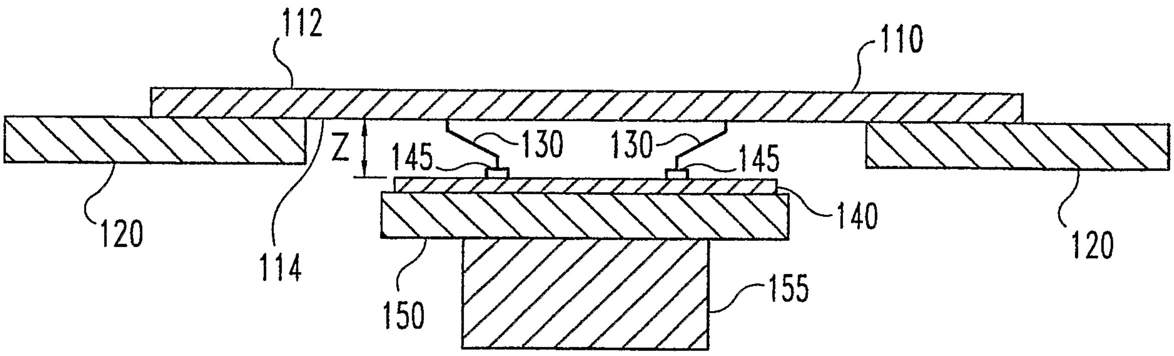


Fig. 8

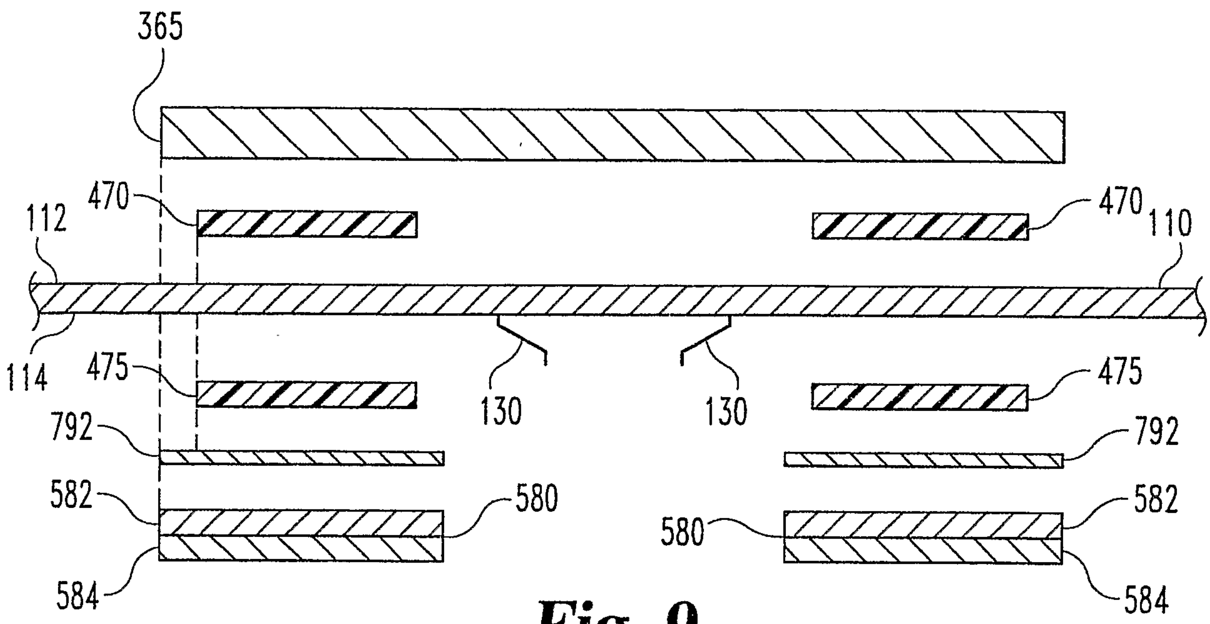

365
470
470
112
110
114
475
130
130
475
792
792
582
580
580
582
584
584

Fig. 9

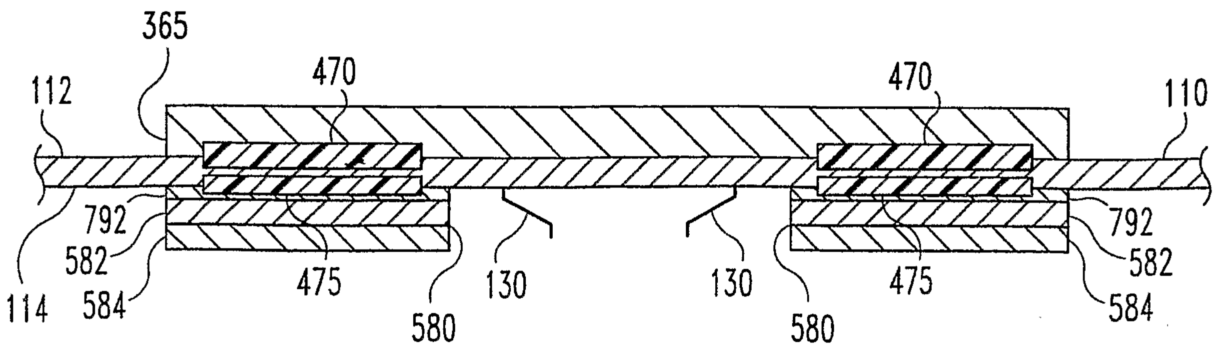

365
470
470
112
110
792
792
582
582
114
584
475
130
130
475
584
580
580

Fig. 9A

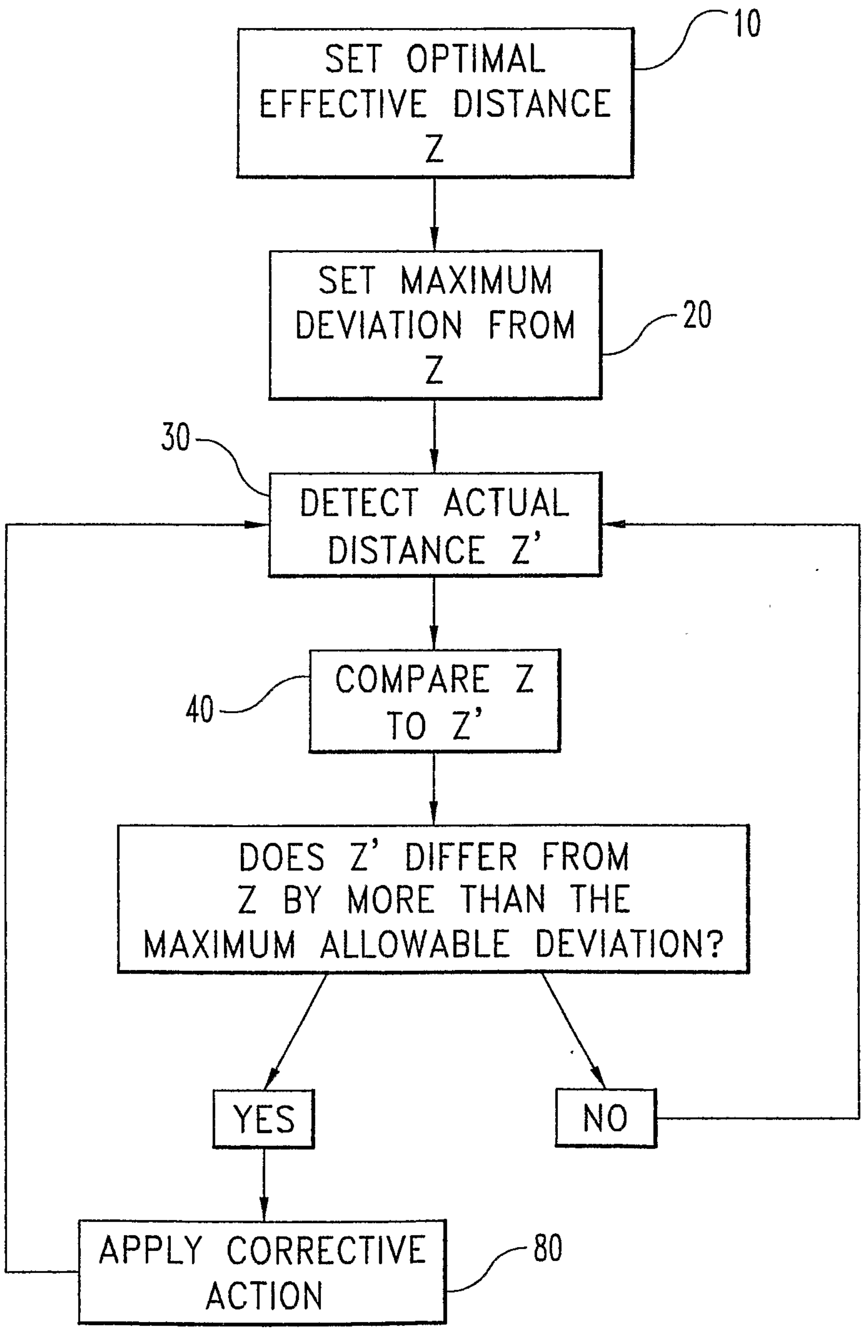

SET OPTIMAL EFFECTIVE DISTANCE Z
10
SET MAXIMUM DEVIATION FROM Z
20
30
DETECT ACTUAL DISTANCE Z'
COMPARE Z TO Z'
40
DOES Z' DIFFER FROM Z BY MORE THAN THE MAXIMUM ALLOWABLE DEVIATION?
YES
NO
APPLY CORRECTIVE ACTION
80

Fig. 10

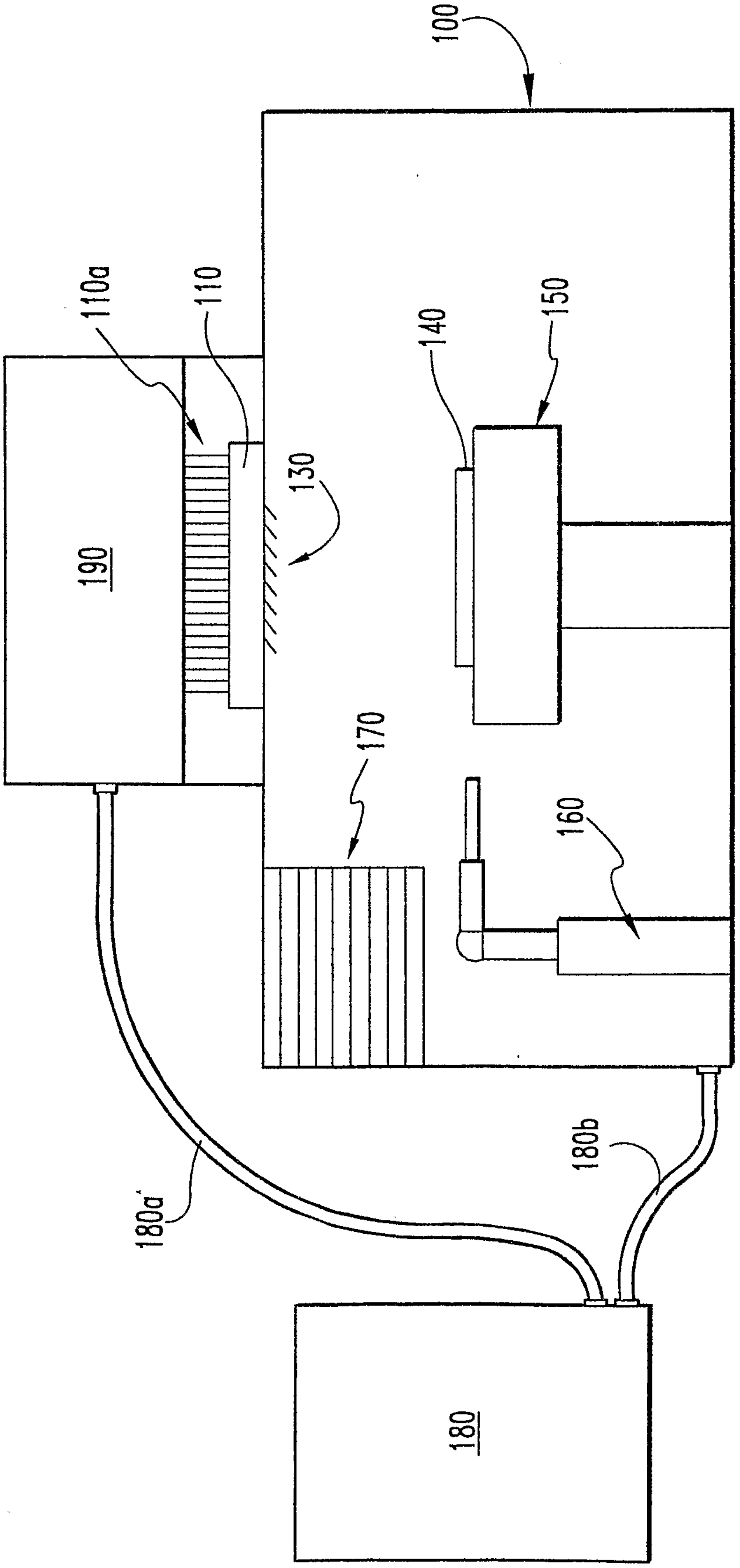


Fig. 11

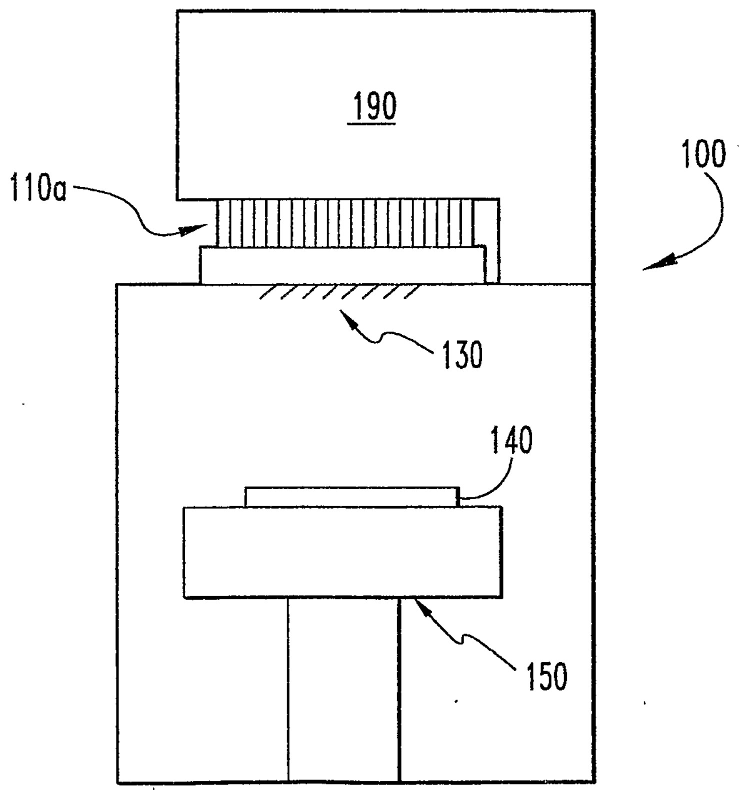


Fig. 12

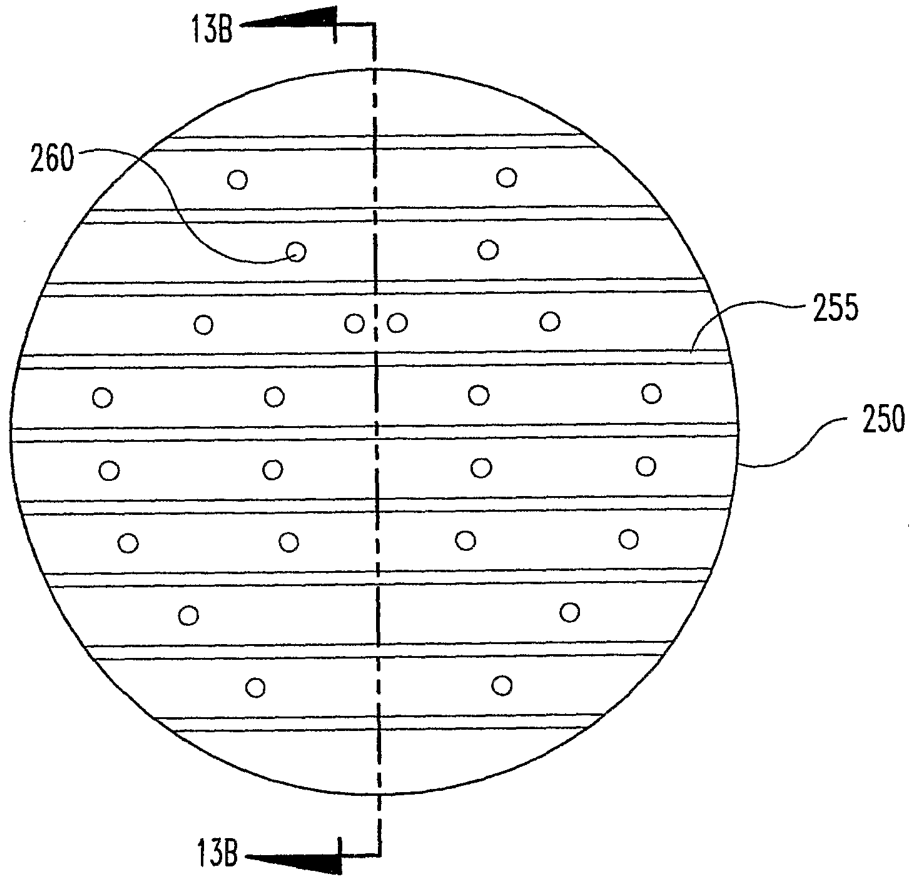


Fig. 13A

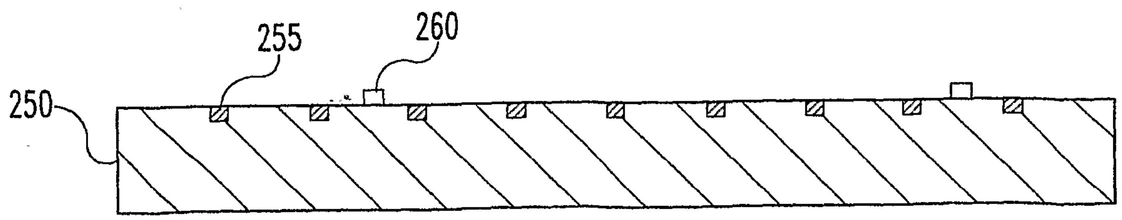


Fig. 13B

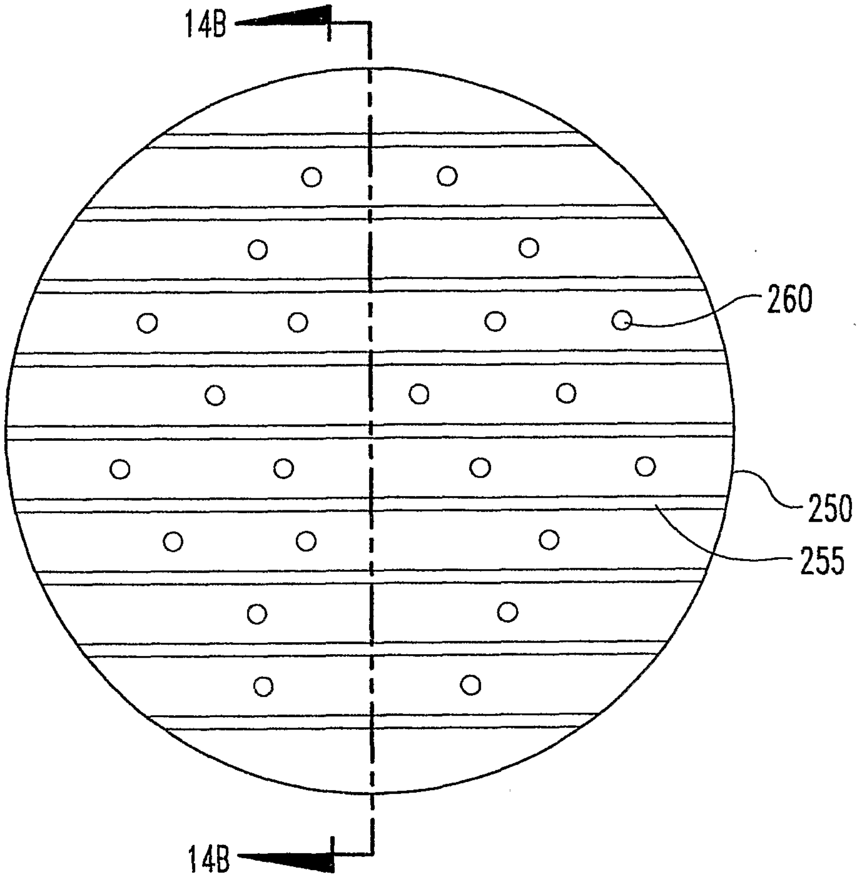


Fig. 14A

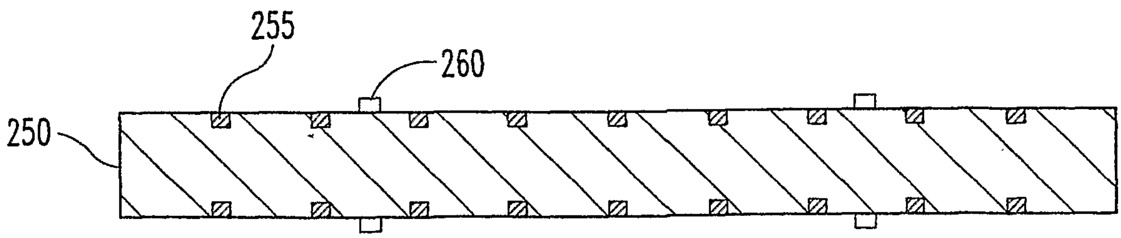


Fig. 14B

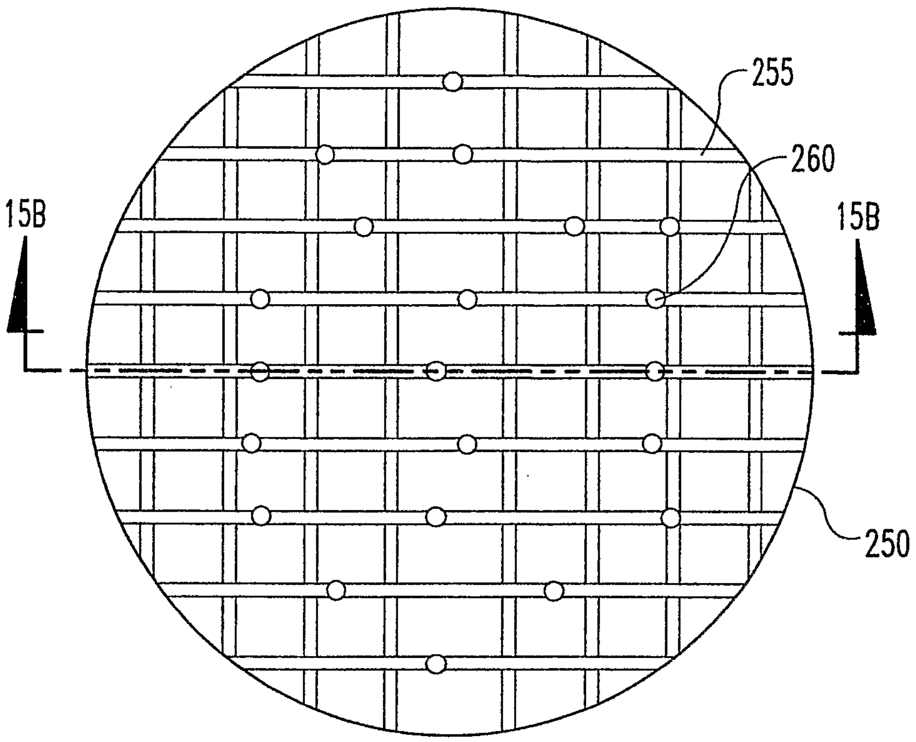


Fig. 15A

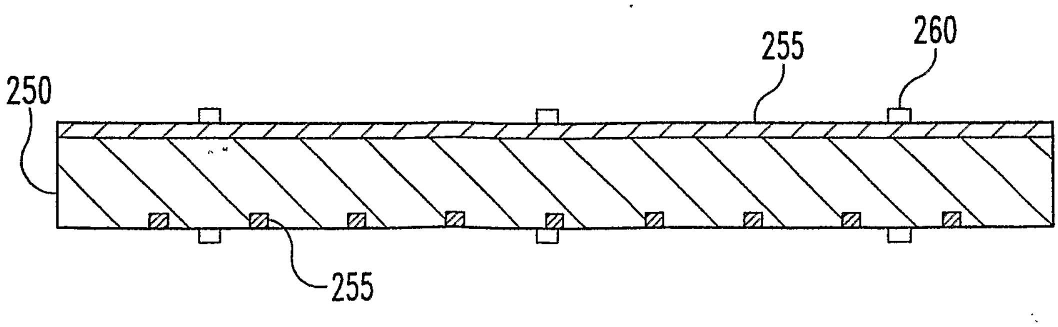


Fig. 15B

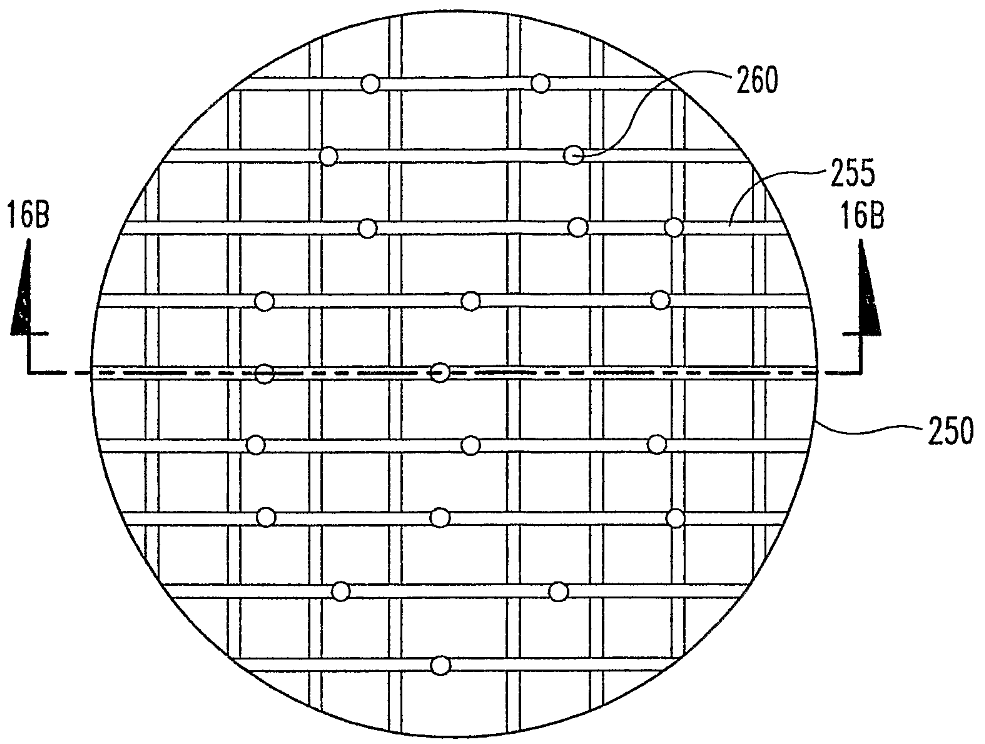


Fig. 16A

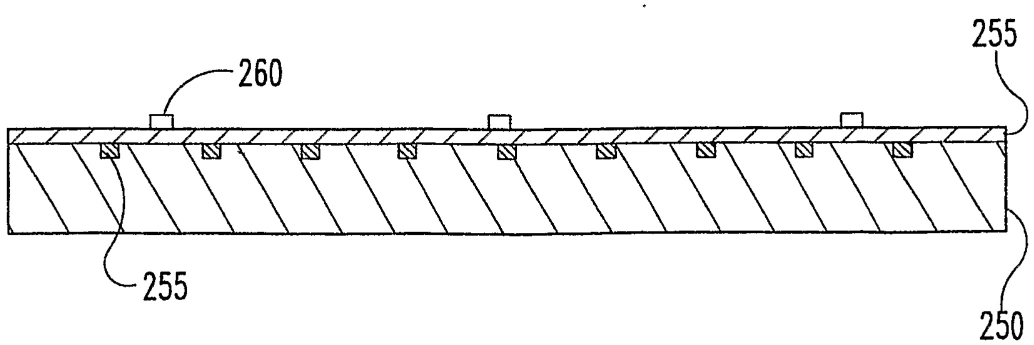


Fig. 16B

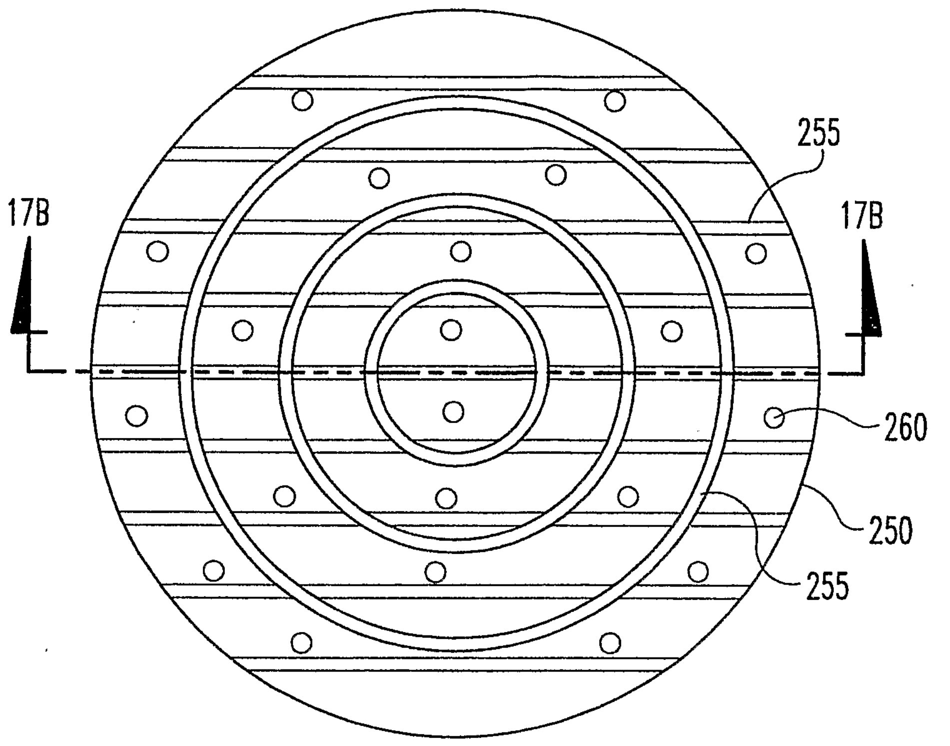


Fig. 17A

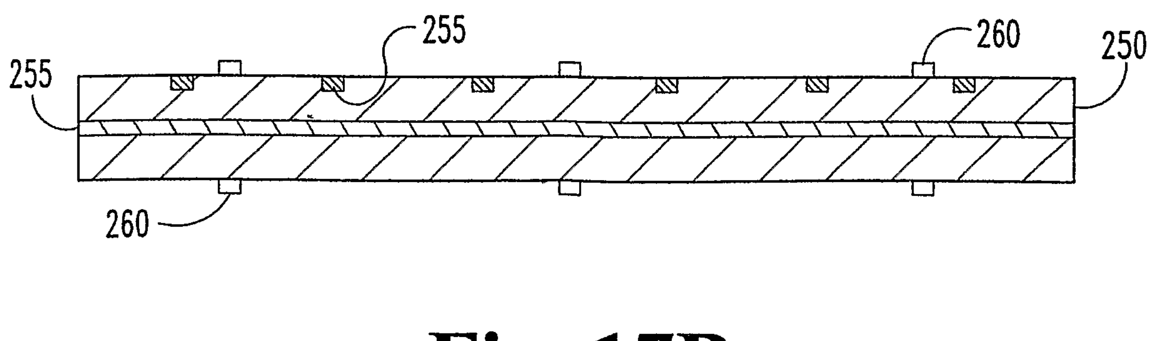


Fig. 17B

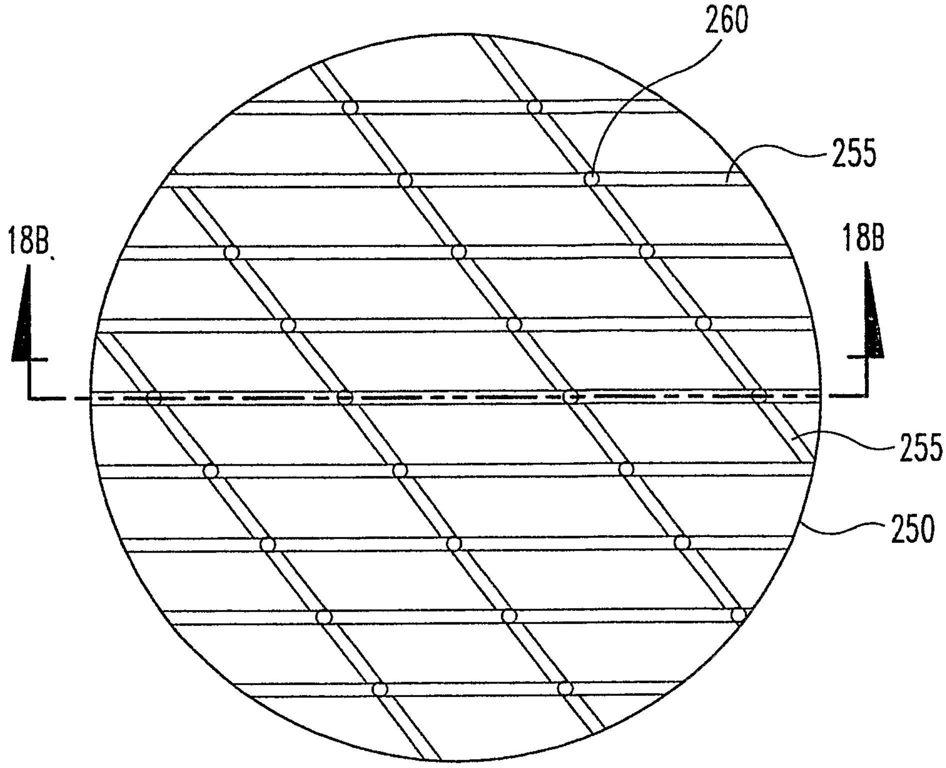


Fig. 18A

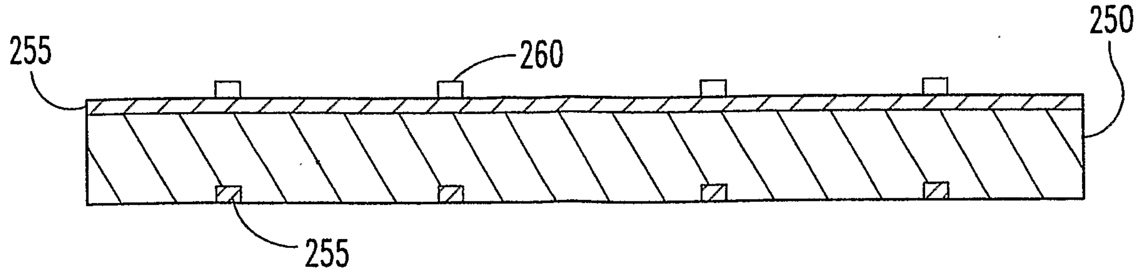


Fig. 18B

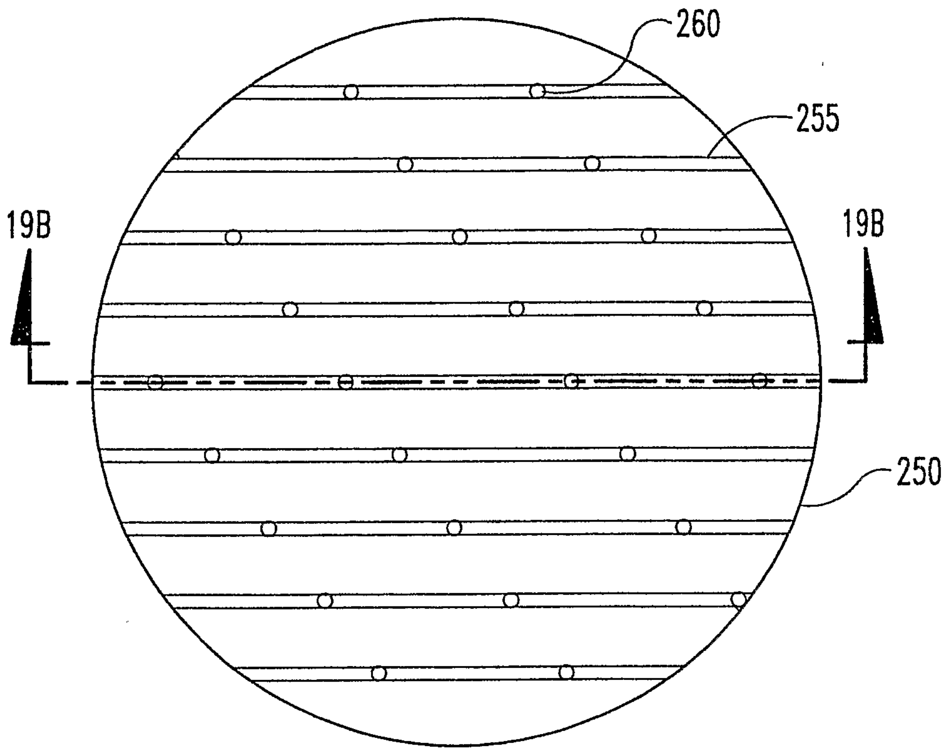


Fig. 19A

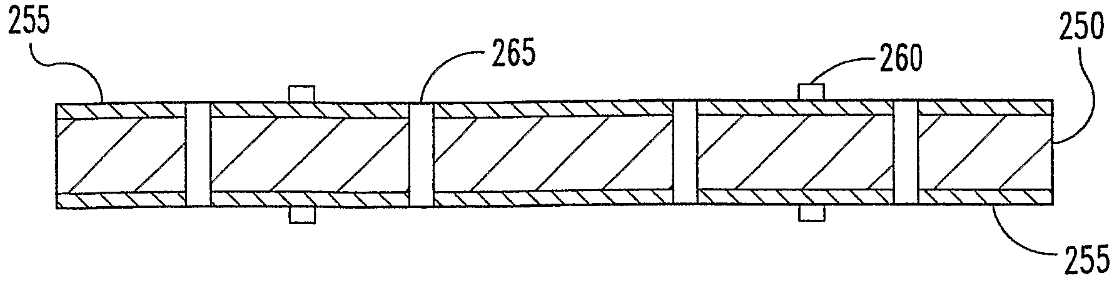


Fig. 19B

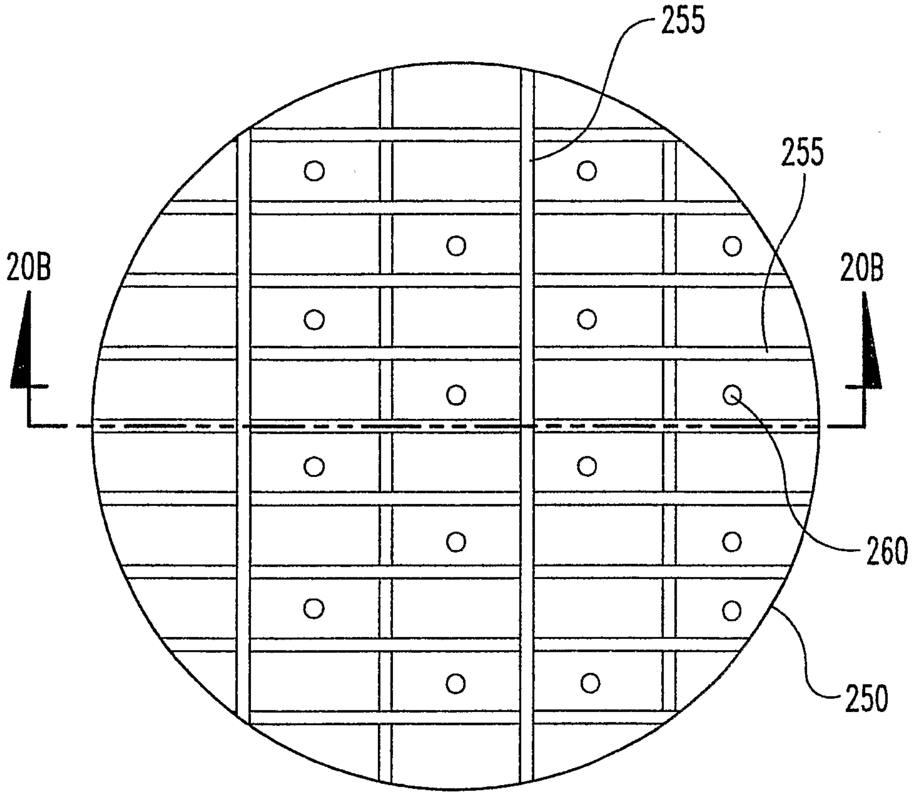


Fig. 20A

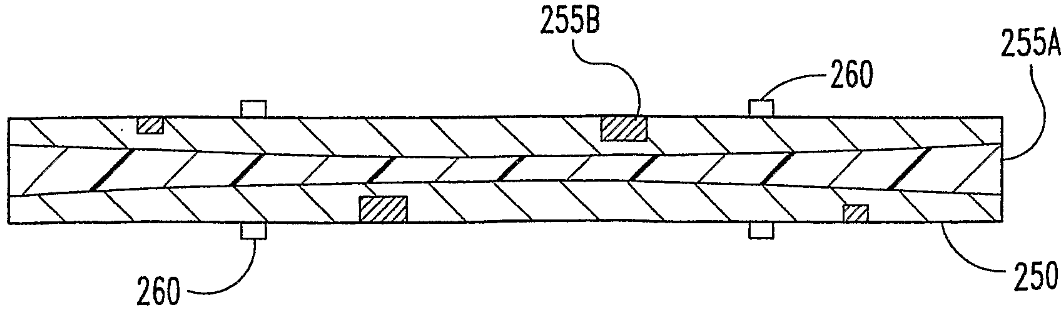


Fig. 20B

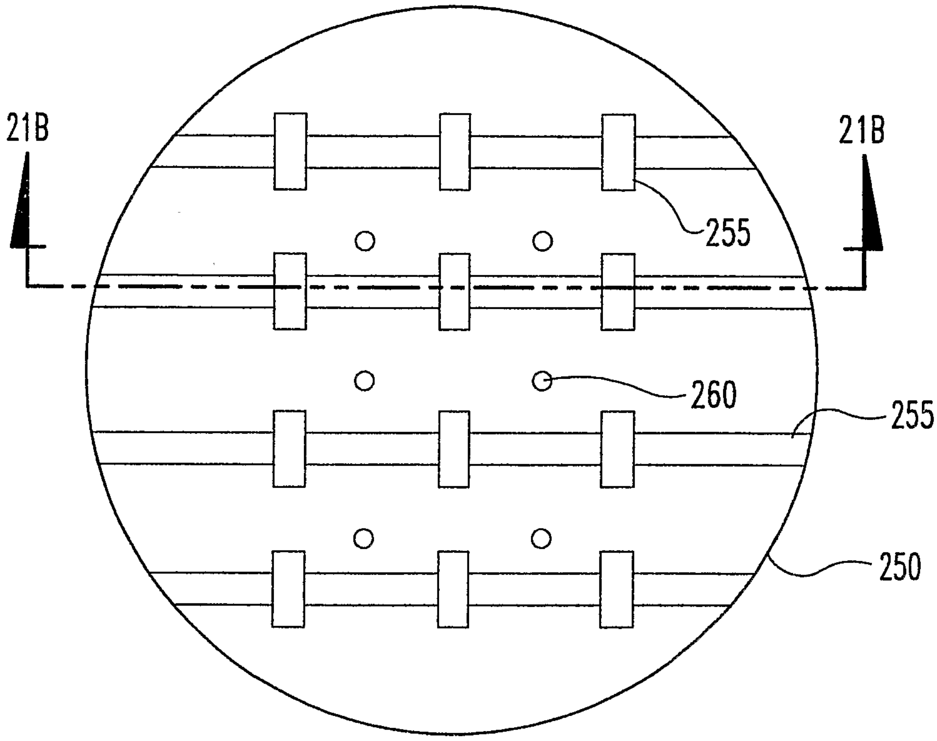


Fig. 21A

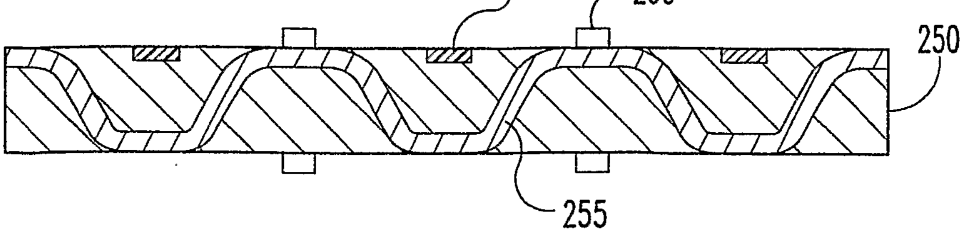


Fig. 21B

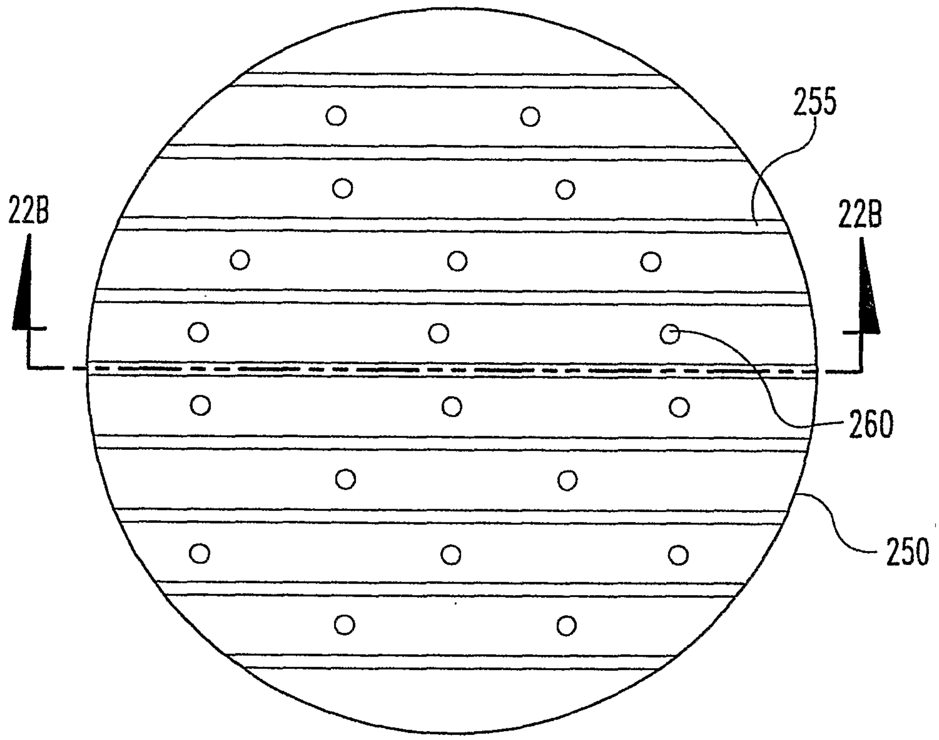


Fig. 22A

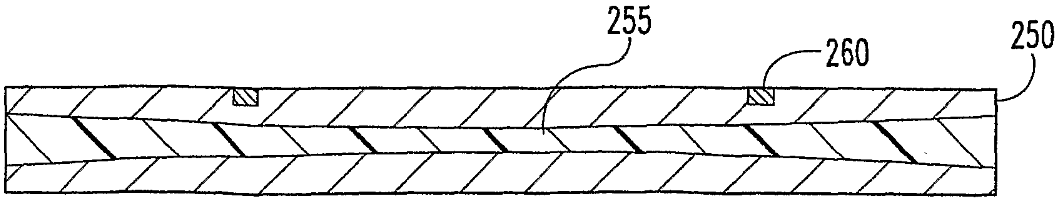


Fig. 22B

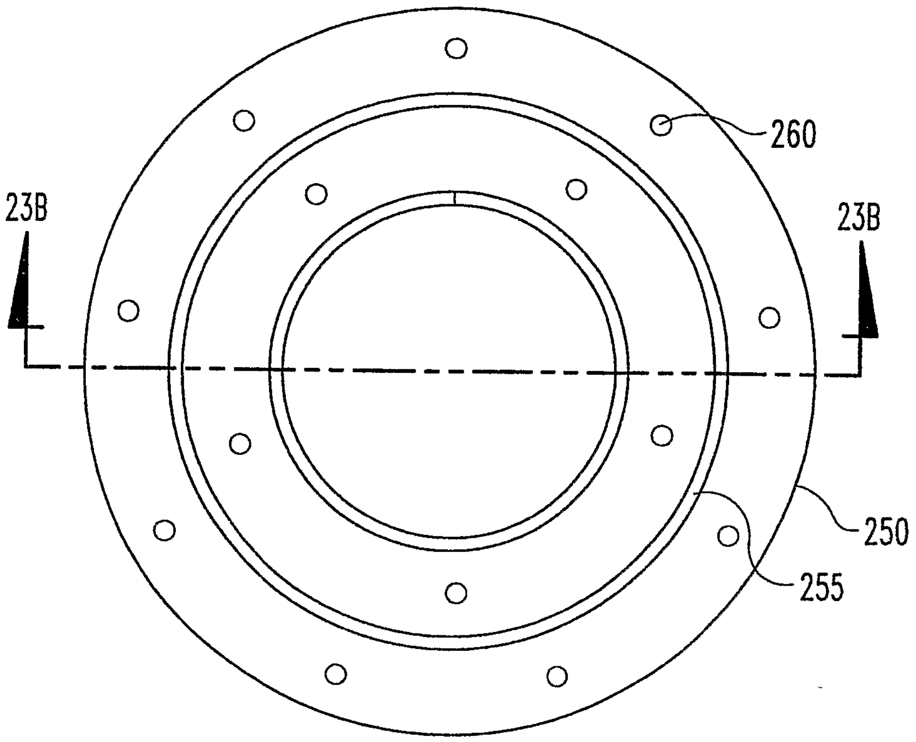


Fig. 23A

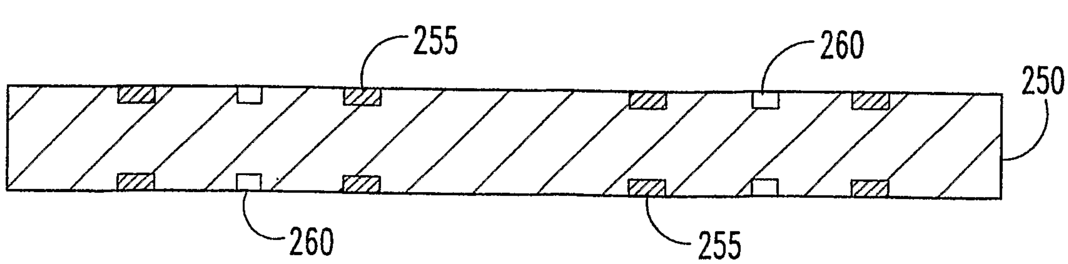


Fig. 23B

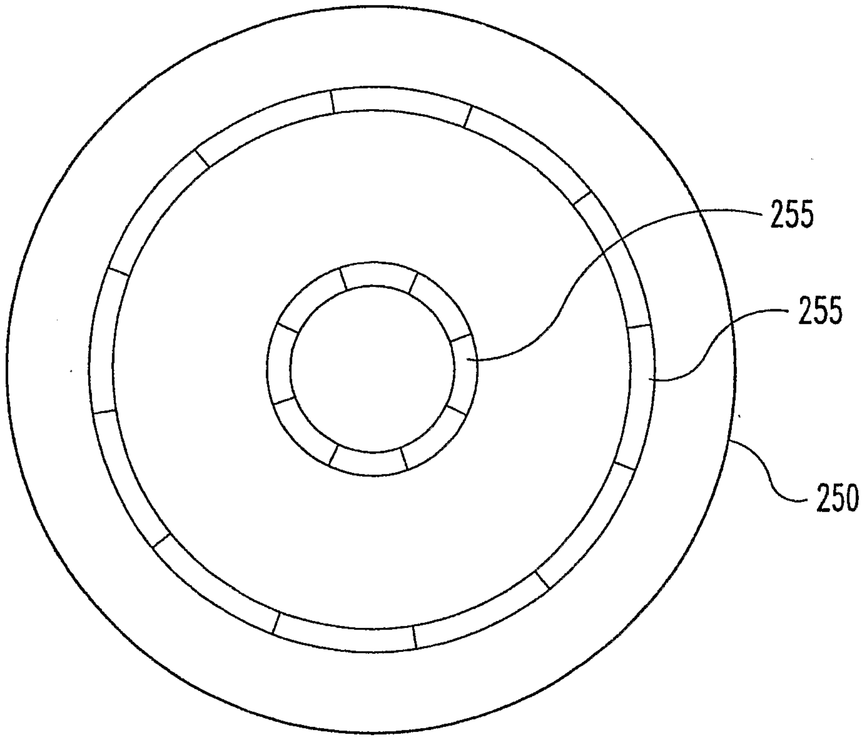


Fig. 24A

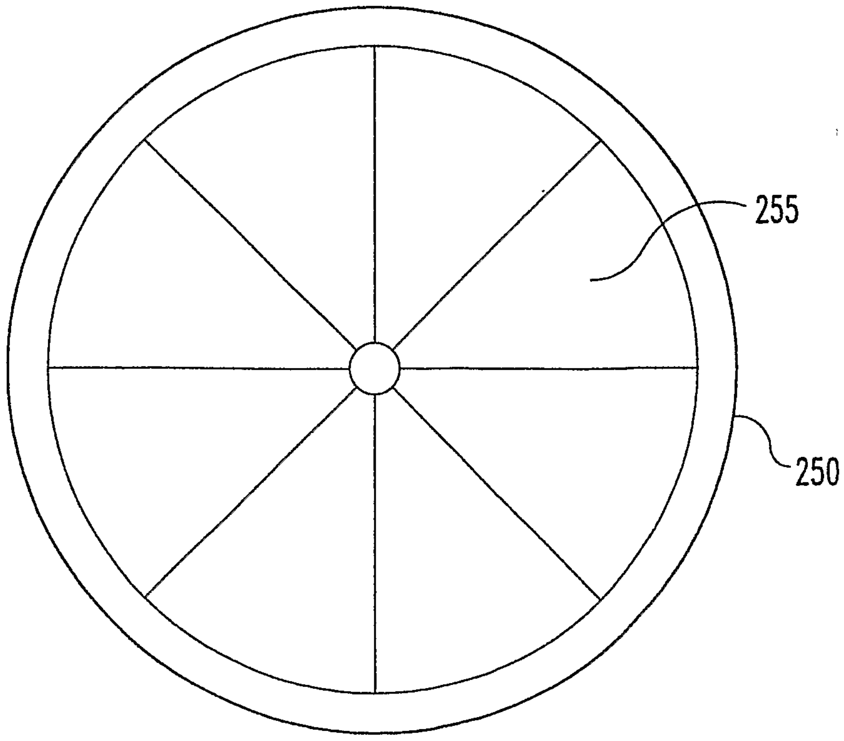


Fig. 24B

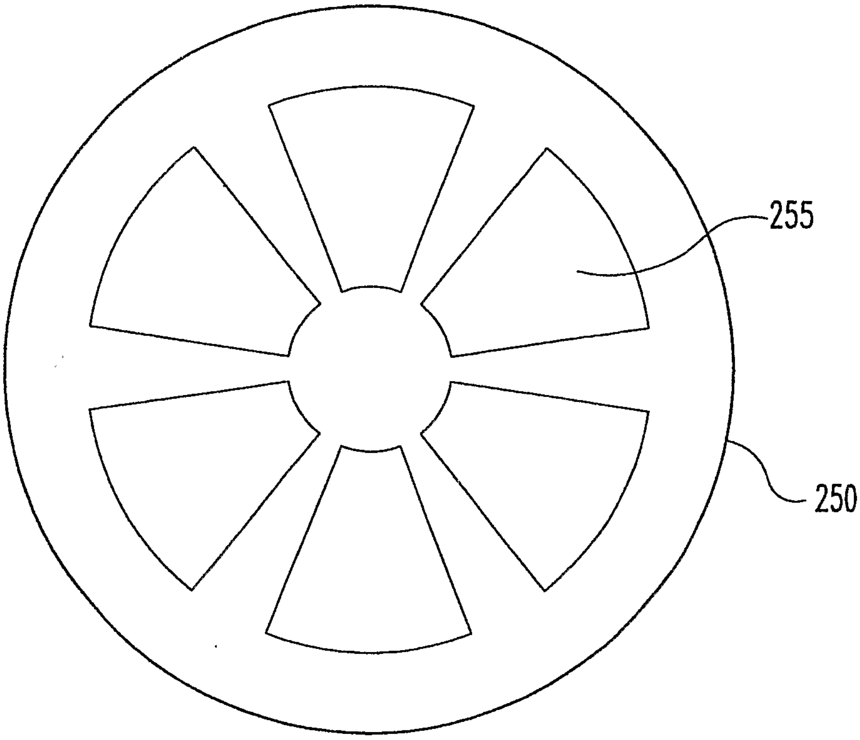


Fig. 24C

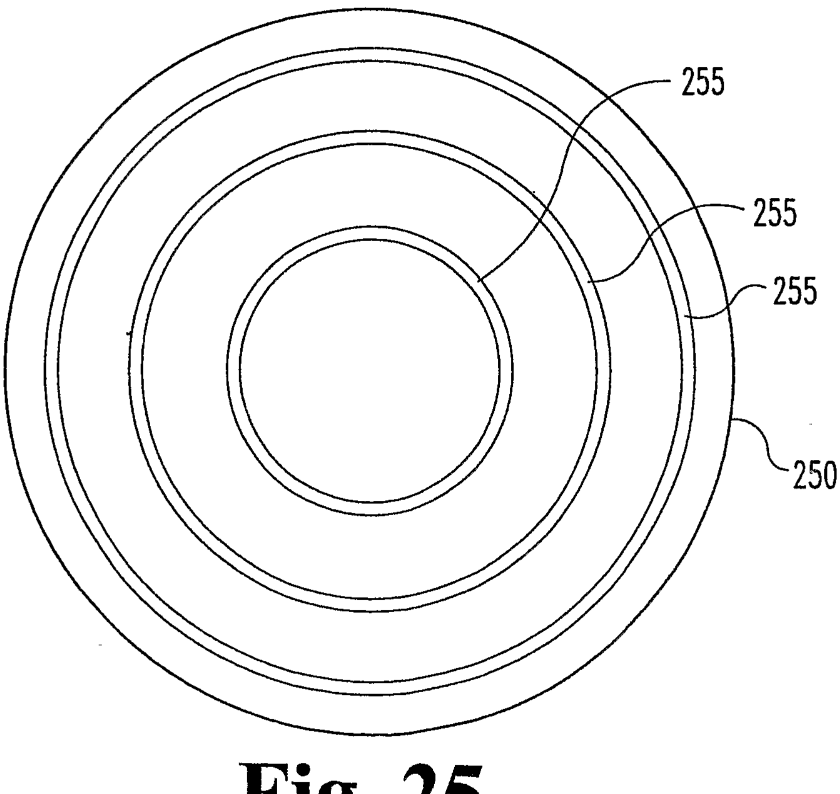


Fig. 25

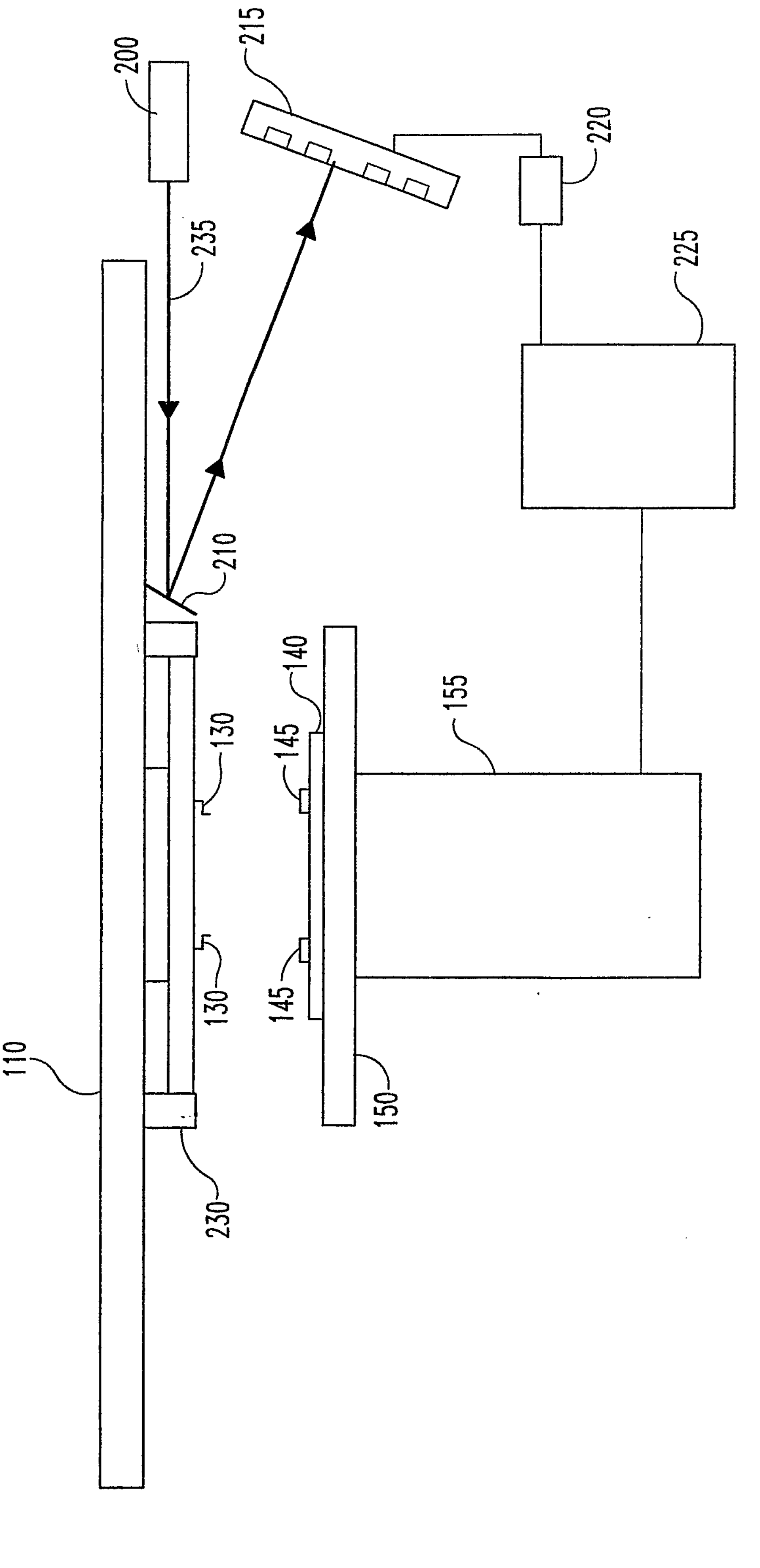


Fig. 26

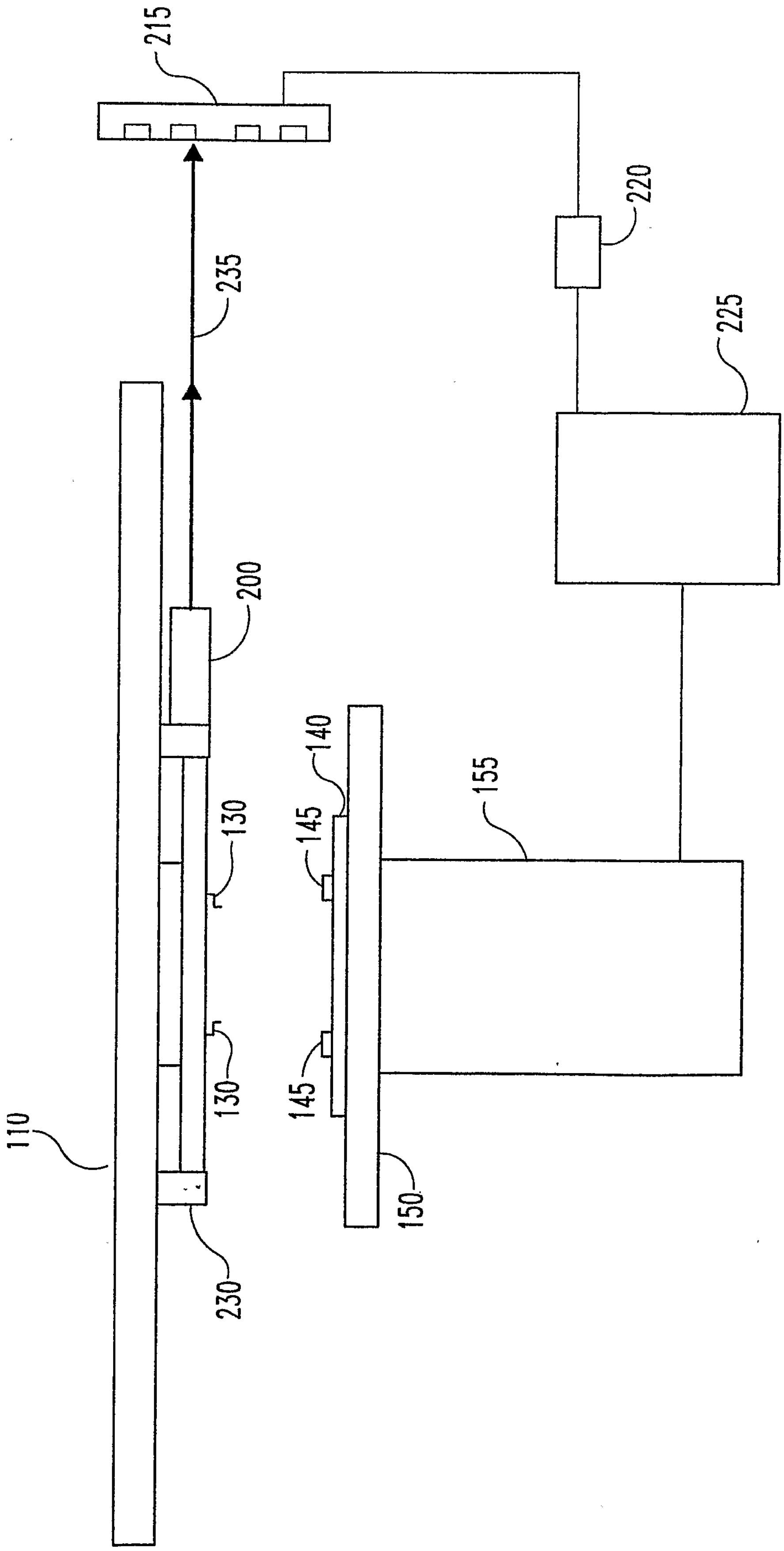
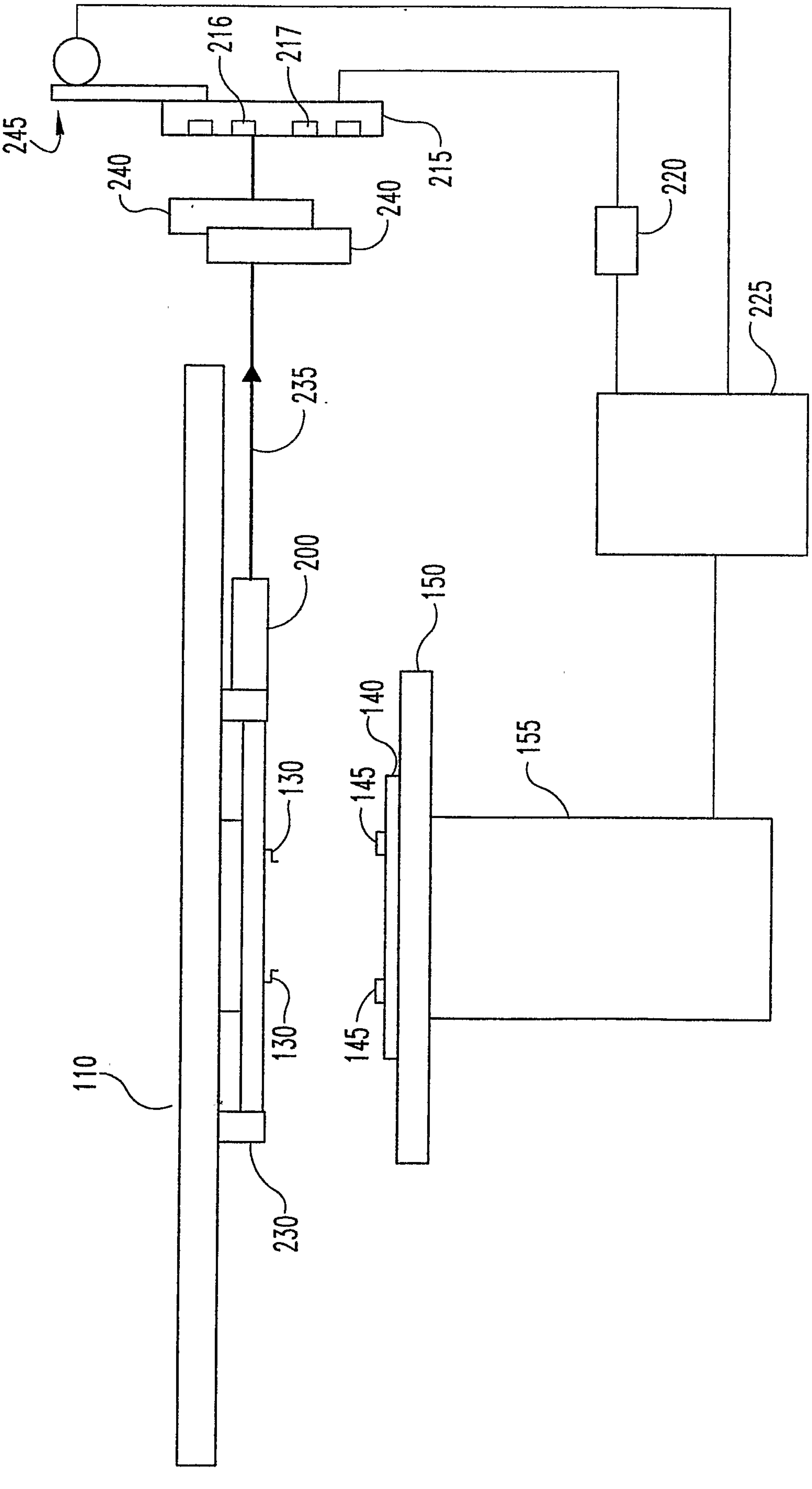


Fig. 27


245
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230

Fig. 28

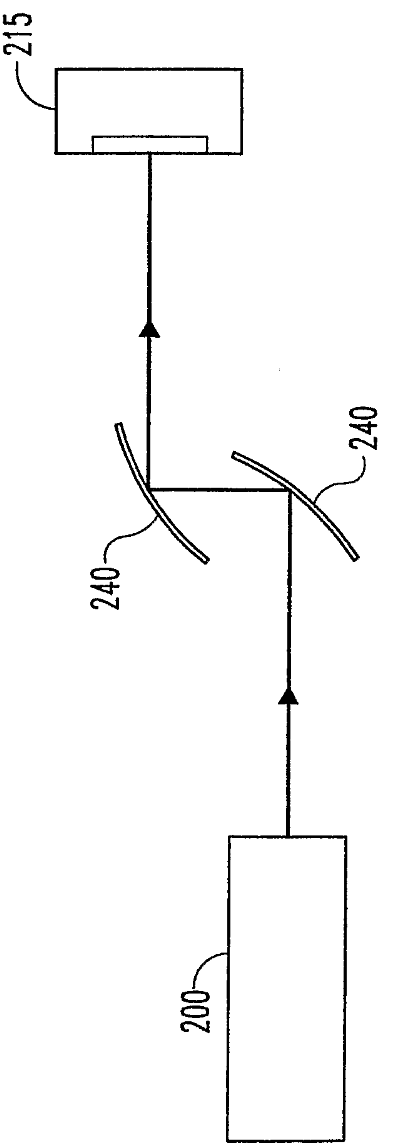

Fig. 28A

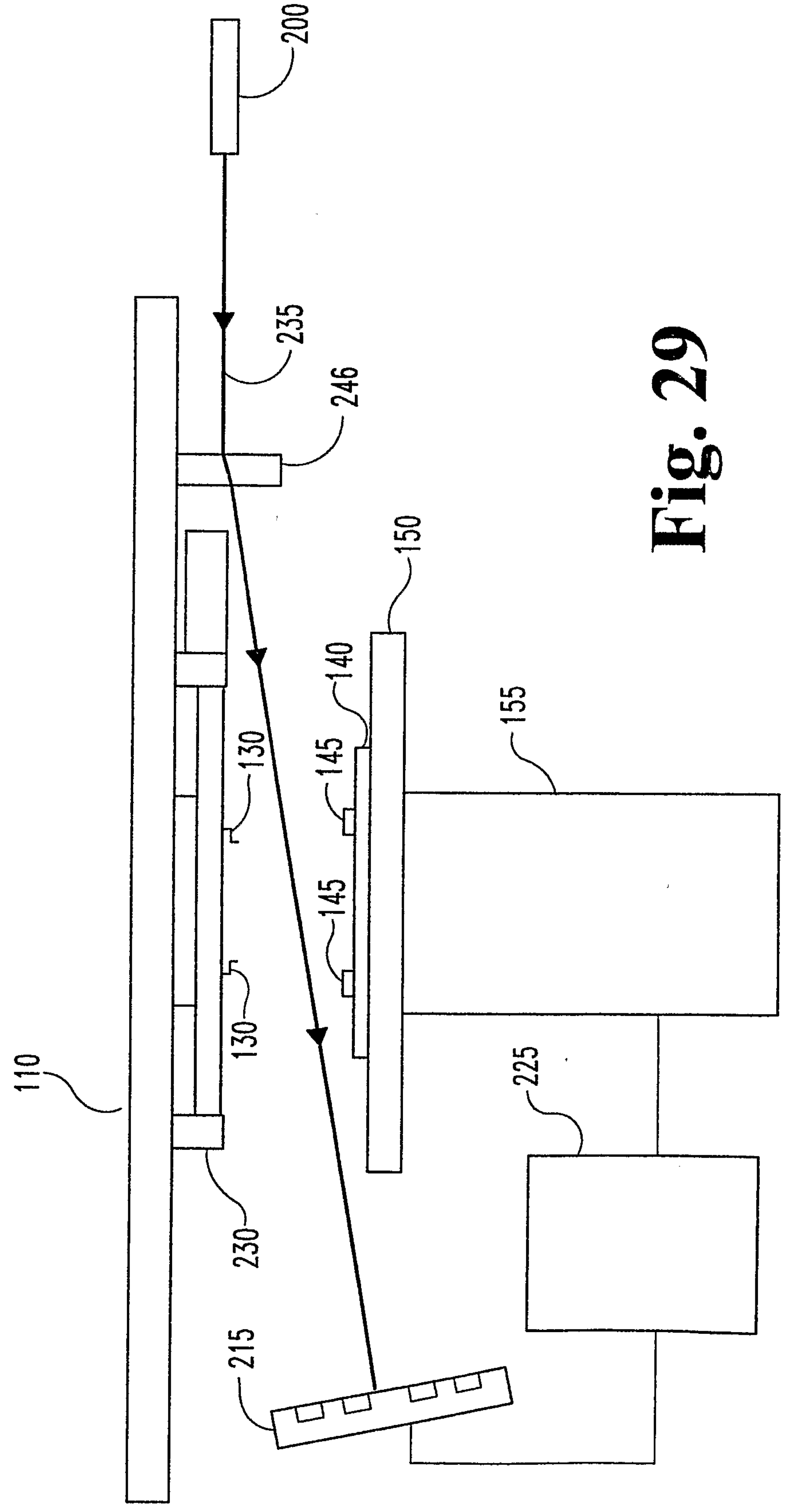

Fig. 29

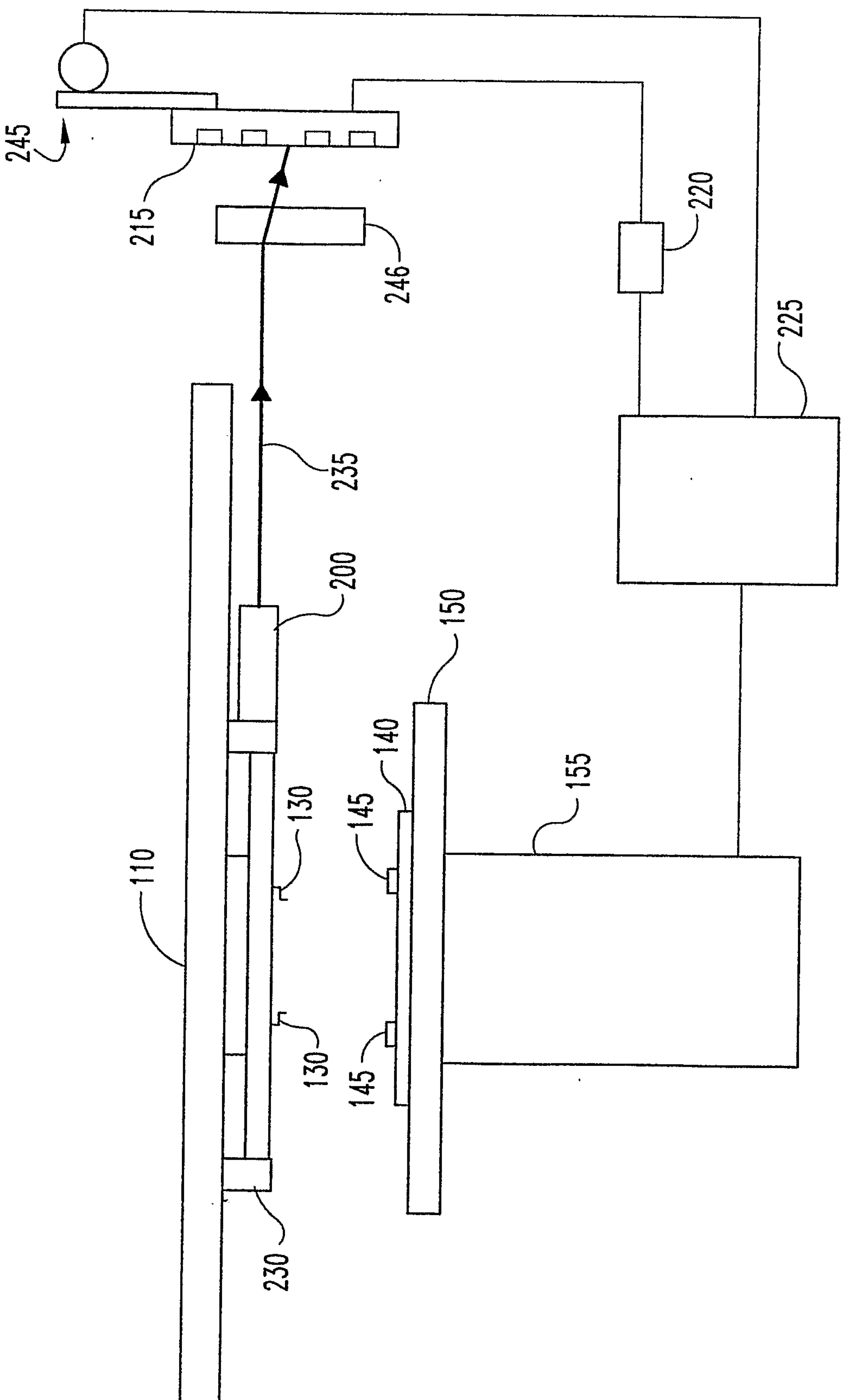

Fig. 30