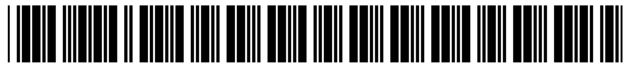

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(54) **KINEMATIC COUPLING**

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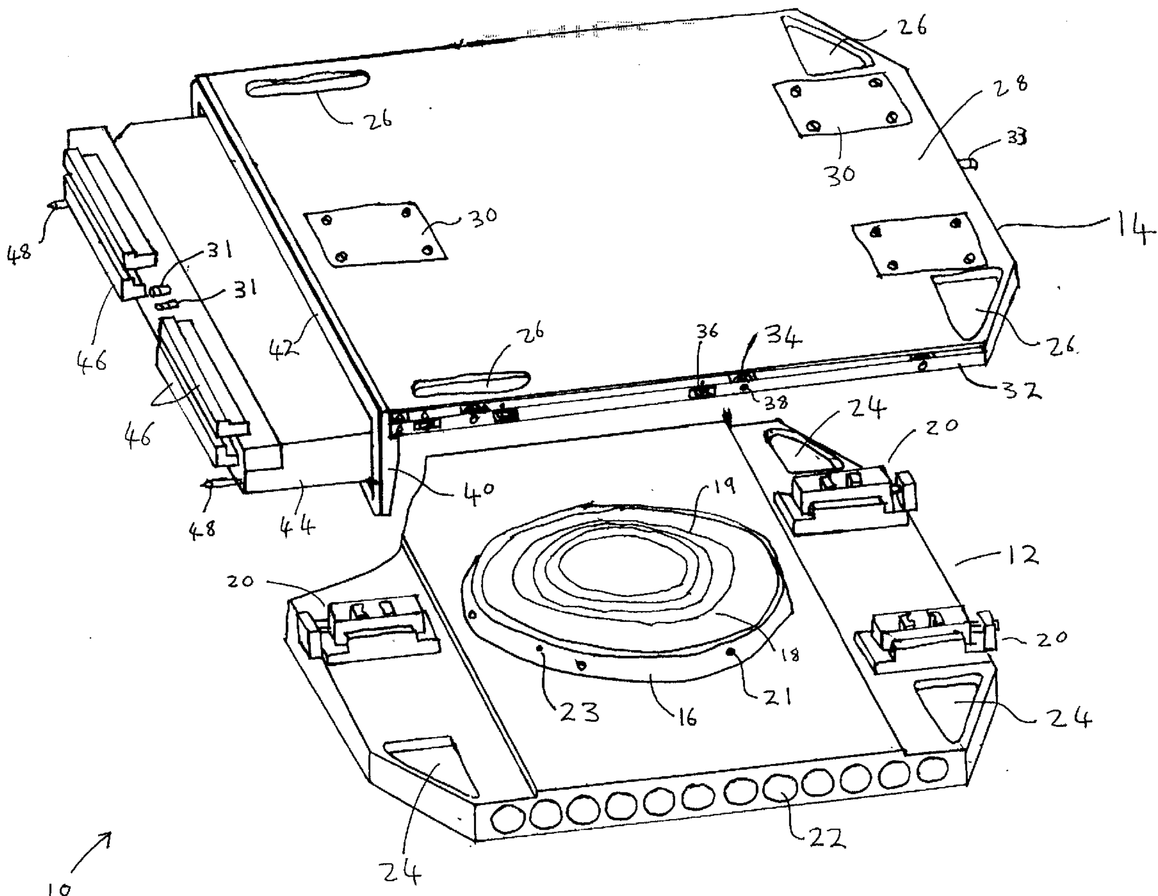
(57) **ABSTRACT**

A kinematic coupling includes a male connector (**94**) and first and second opposed jaws (**122, 124.**) Each of the jaws is pivotable from a retracted position in which the male connector can be inserted between the jaws and an engaging position in which the jaws prevent withdrawal of the male connector from between the jaws. The male connector is movable between an extended and a retracted position, and is biased towards the retracted position. This provides a positive clamping force when the kinematic coupling is engaged.



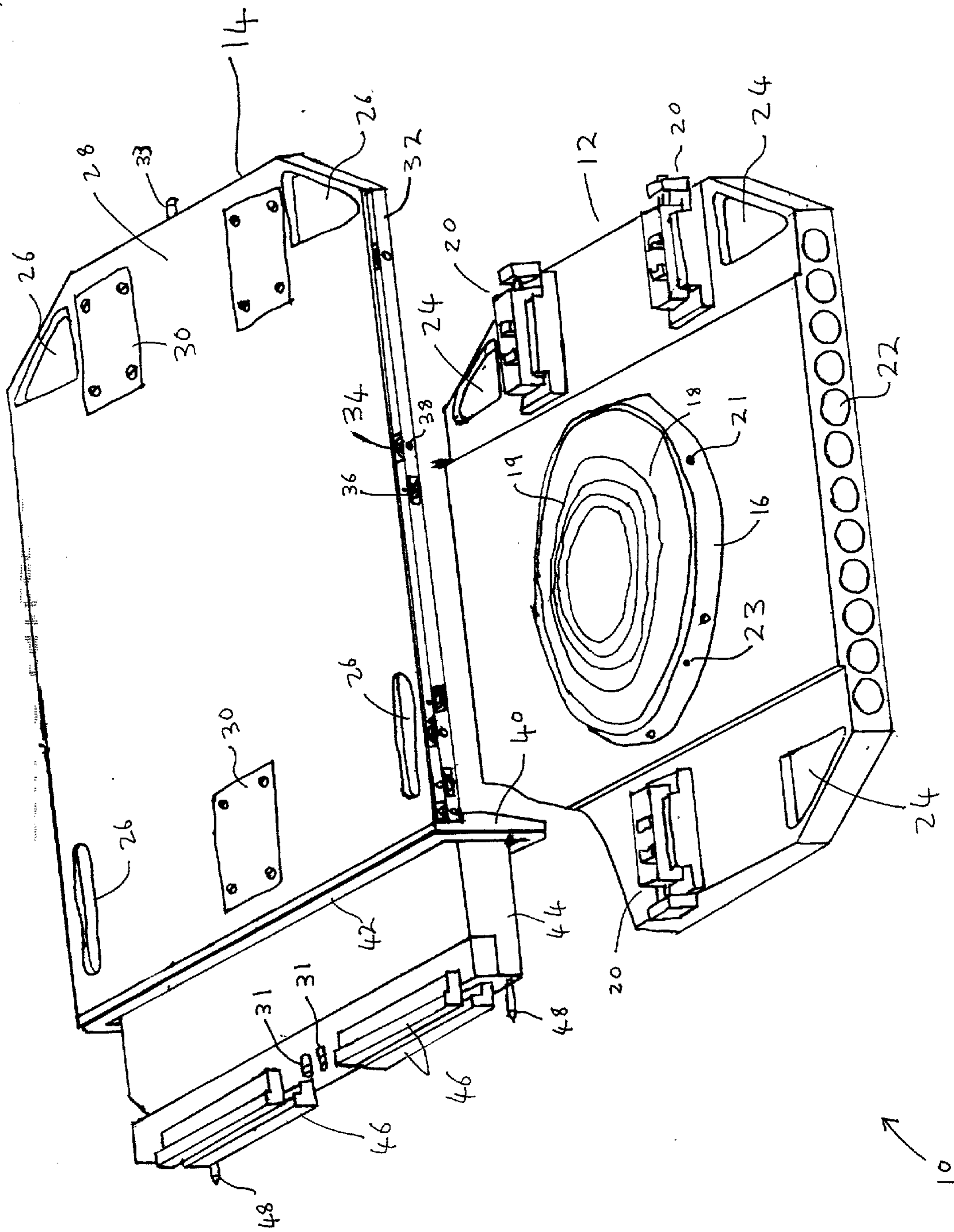


FIG. 1

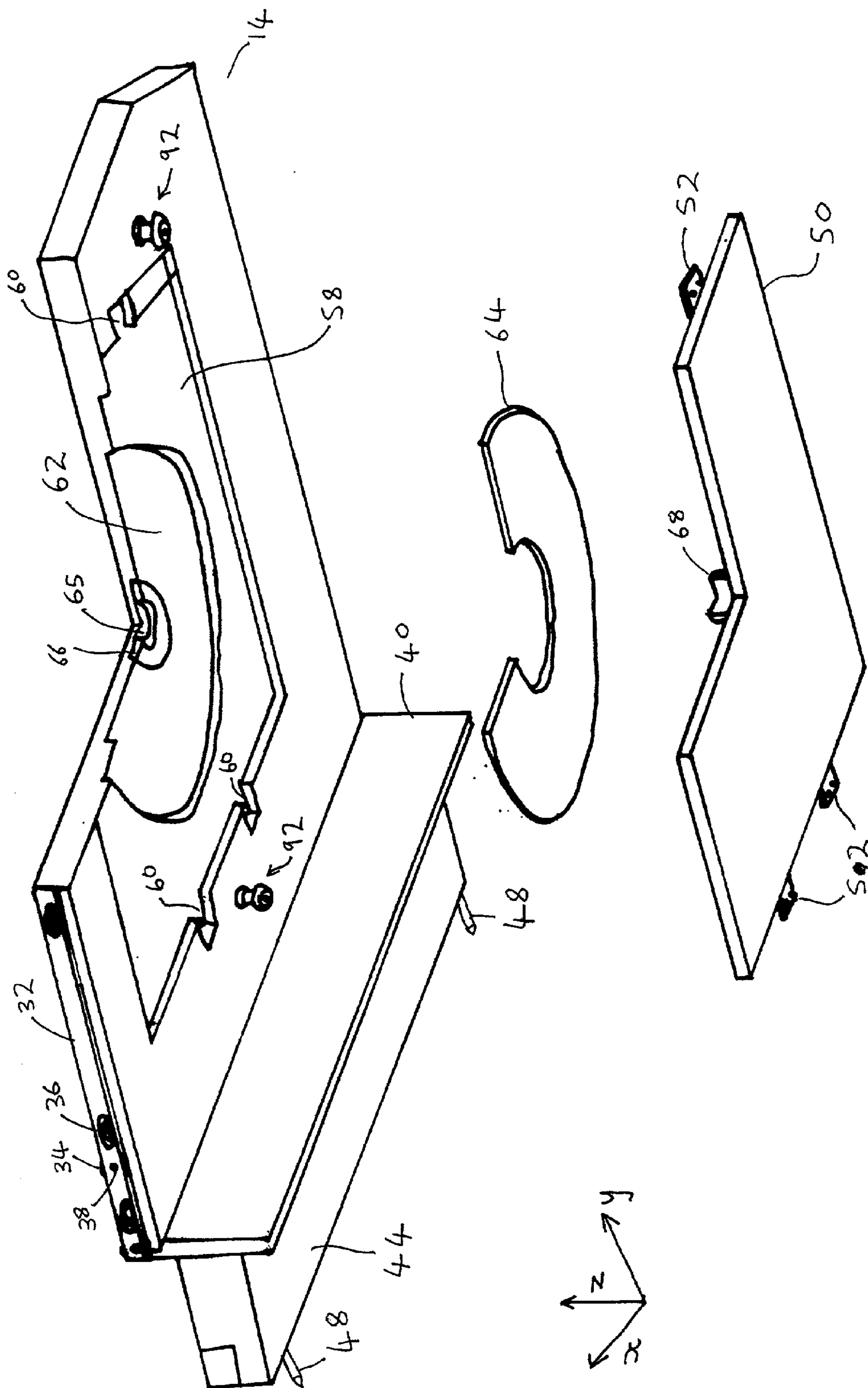


FIG. 2

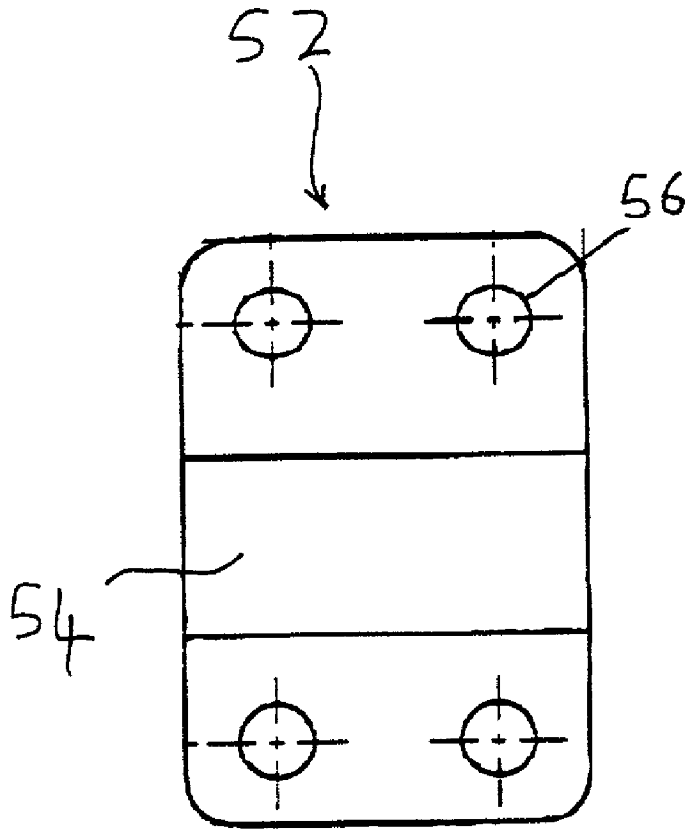


FIG. 3

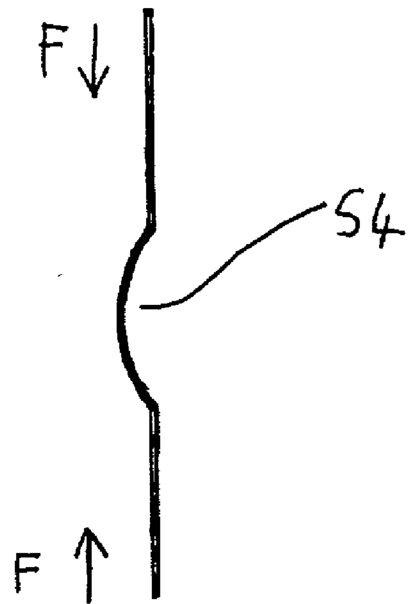
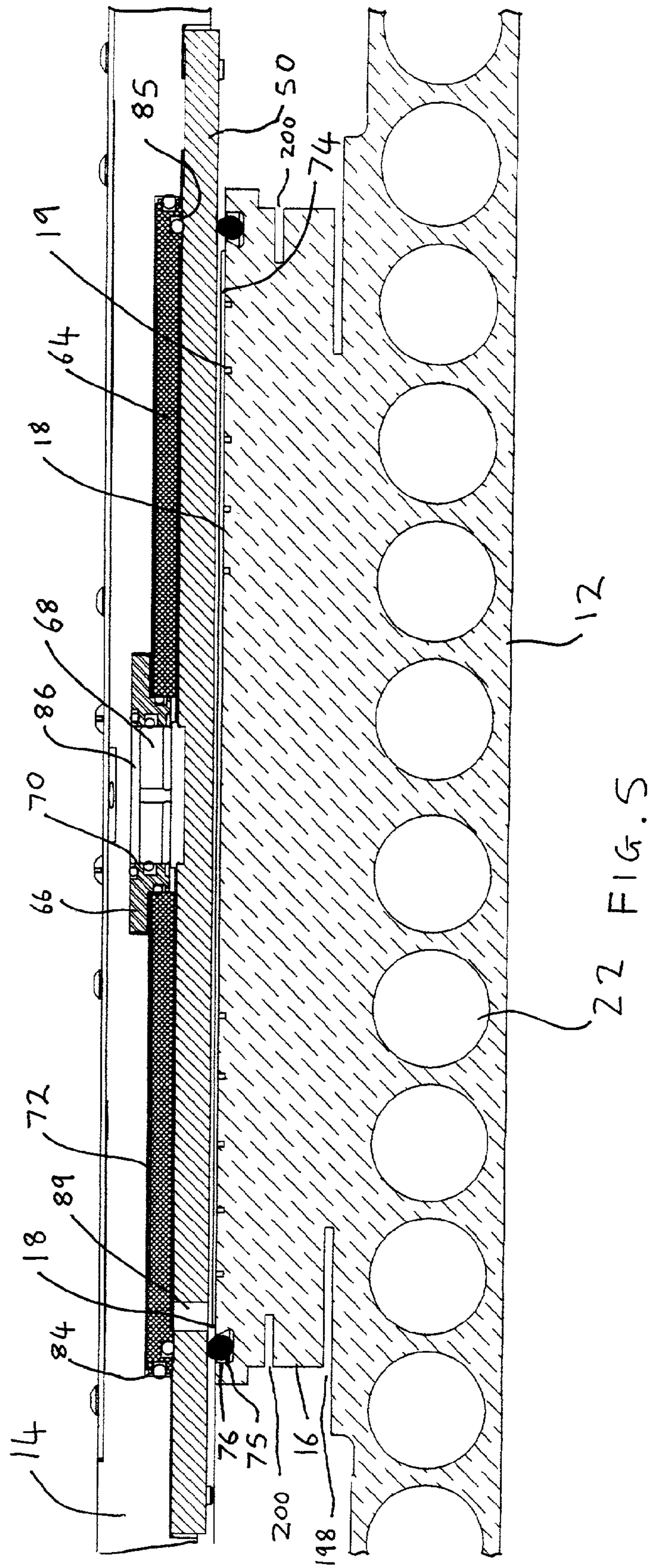


FIG. 4


85
50
200
74
19
64
18
68
86
70
66
72
89
18
84
14
76
75
200
16
198
12
22
FIG. 5

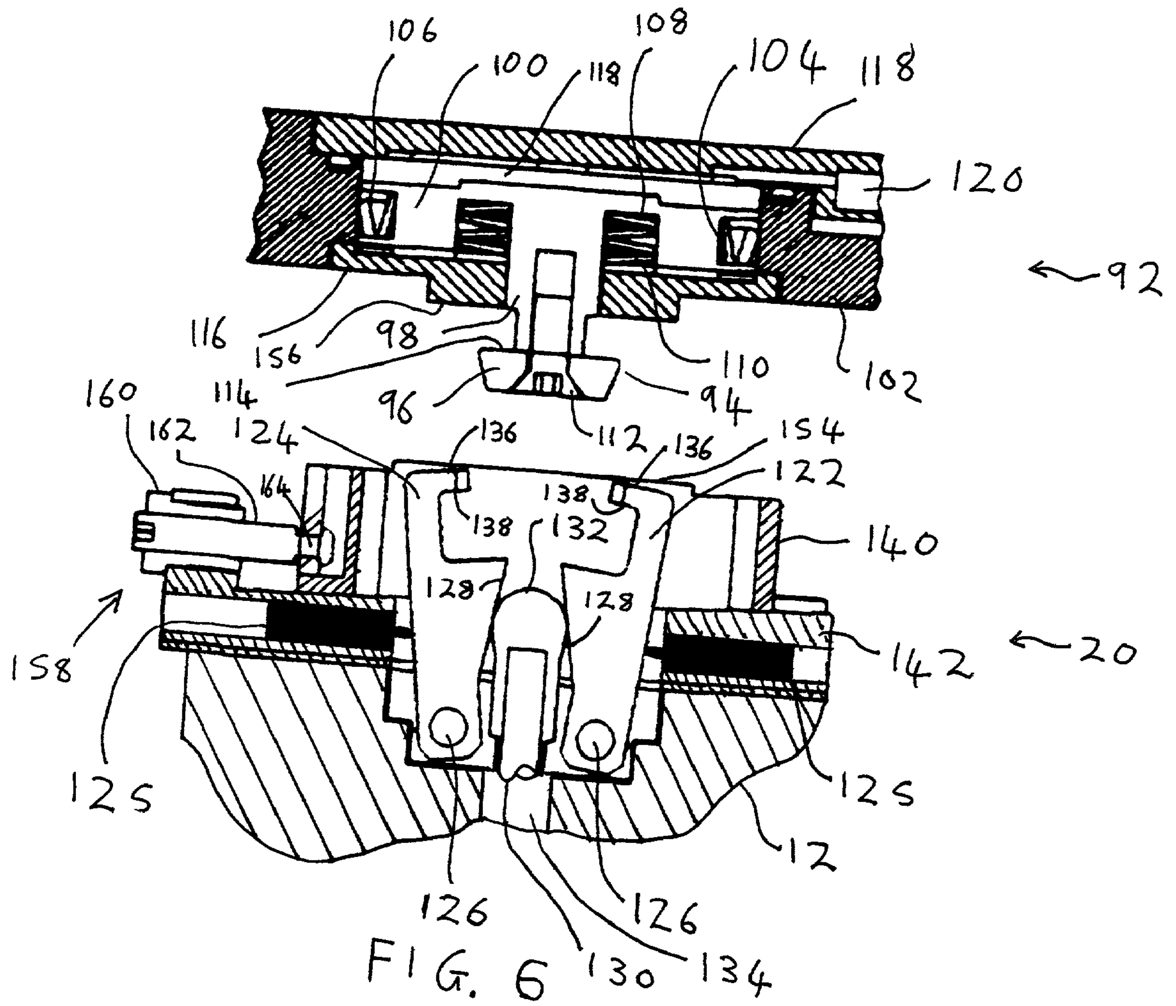


FIG. 6

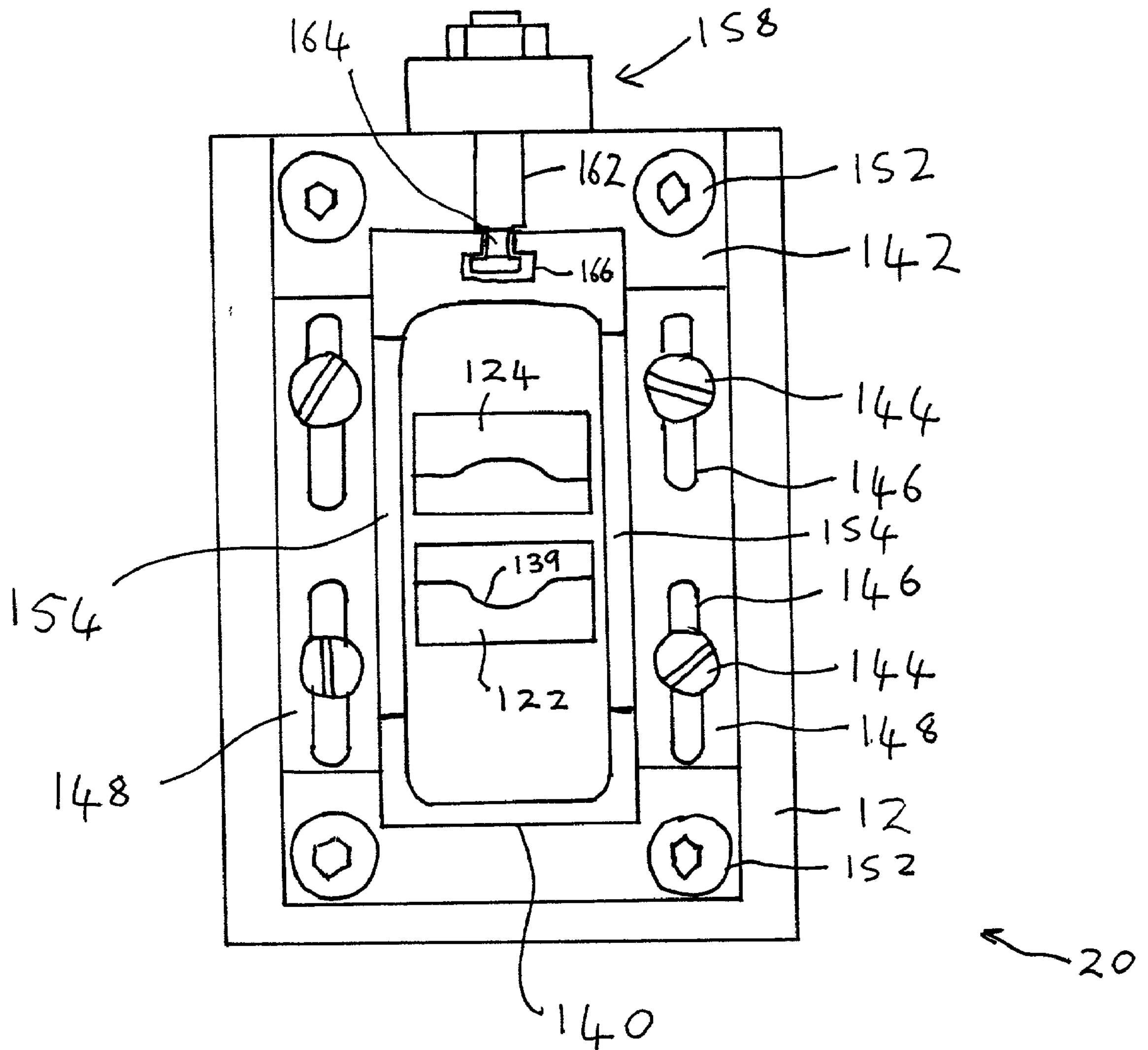


FIG. 7

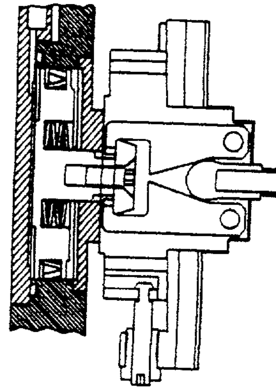


FIG. 8D

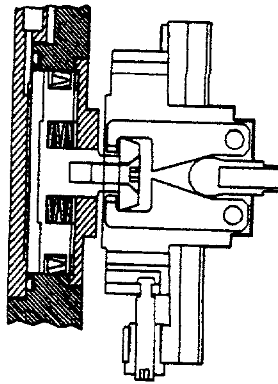


FIG. 8C

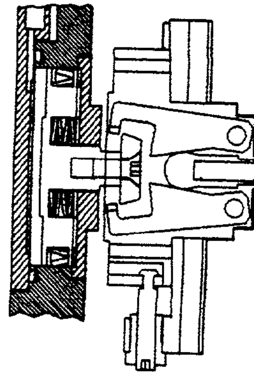


FIG. 8B

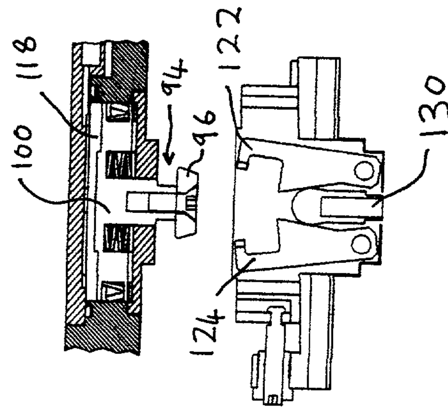


FIG. 8A

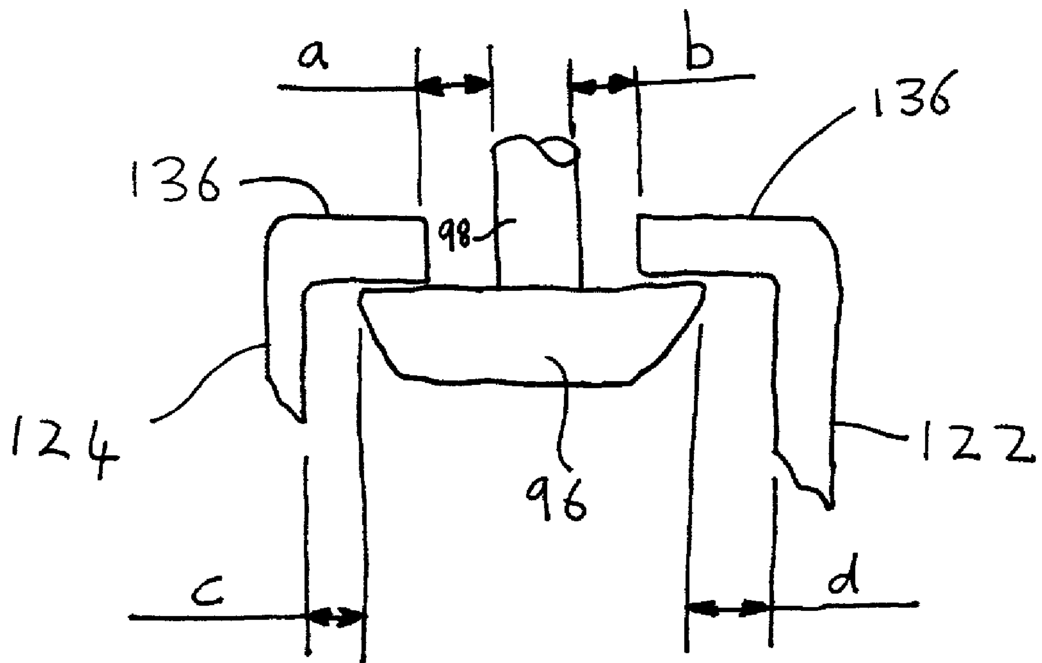


FIG. 9

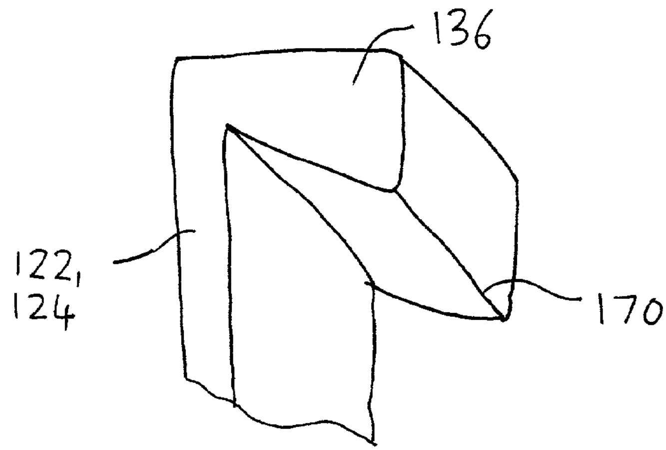


FIG. 10

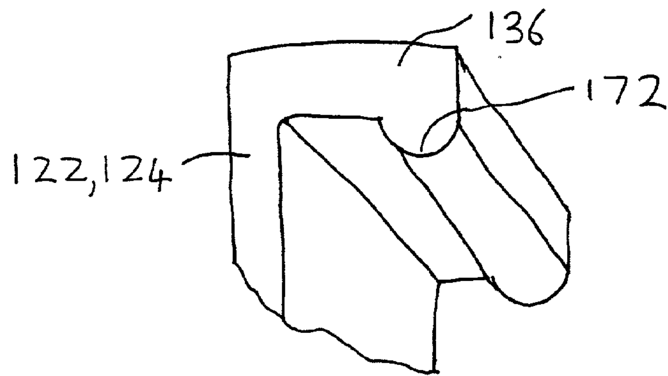


FIG. 11

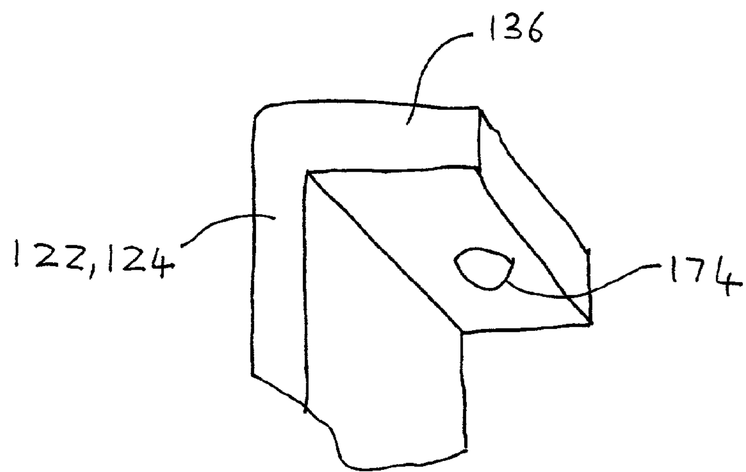


FIG. 12

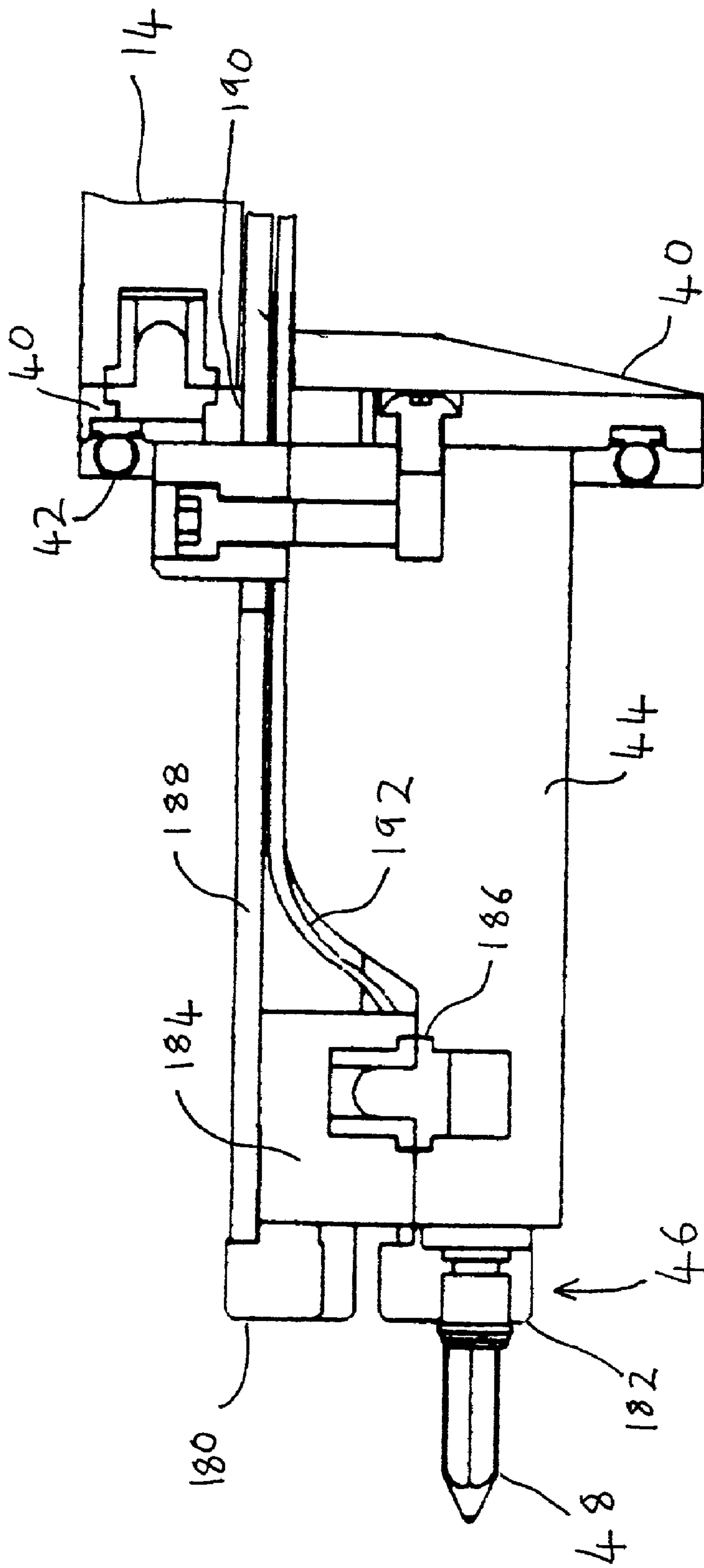


FIG. 13

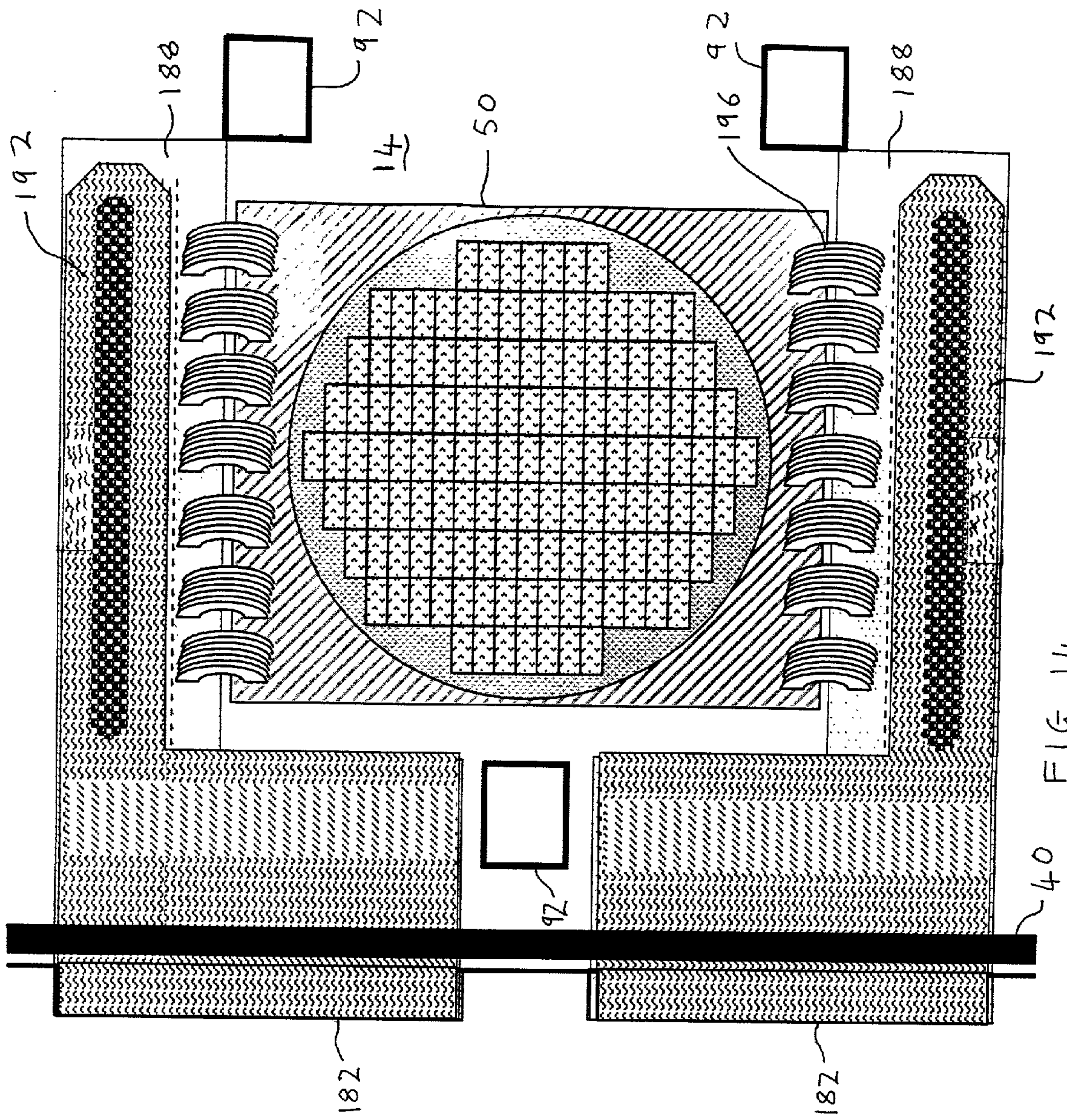


FIG. 14

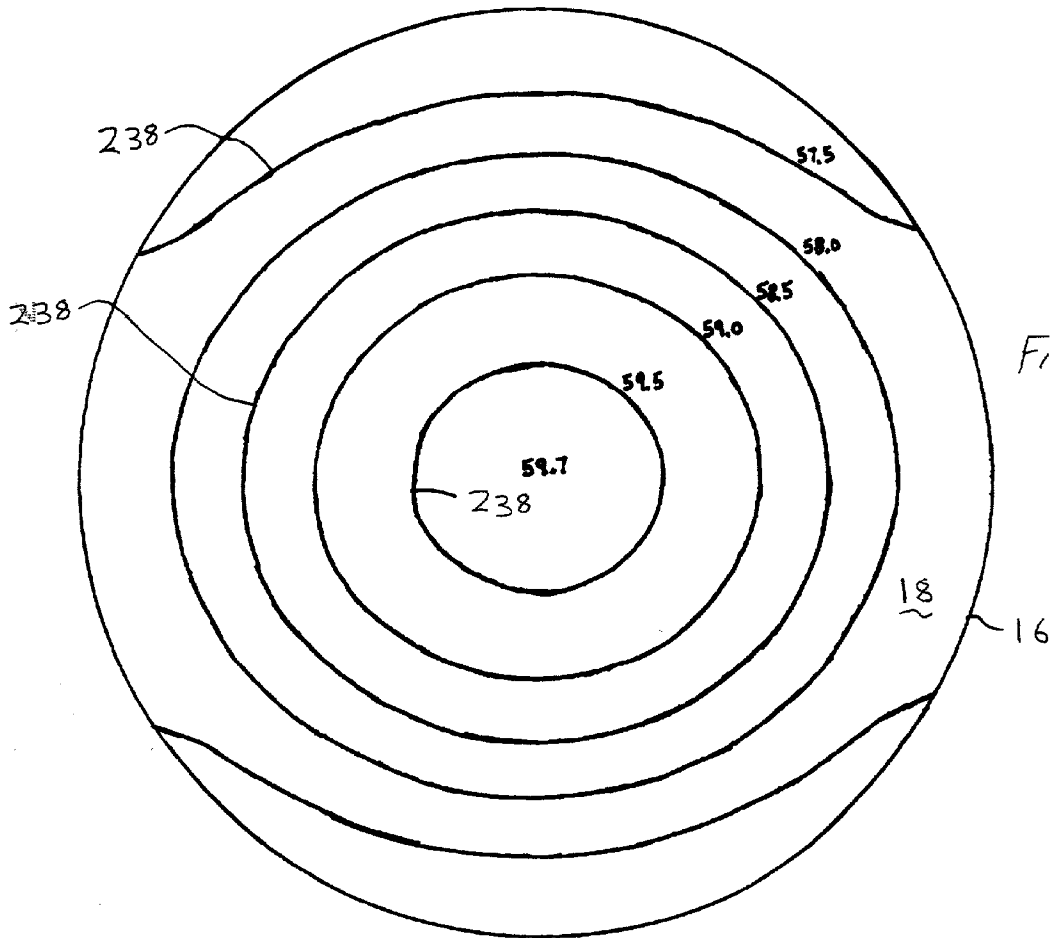
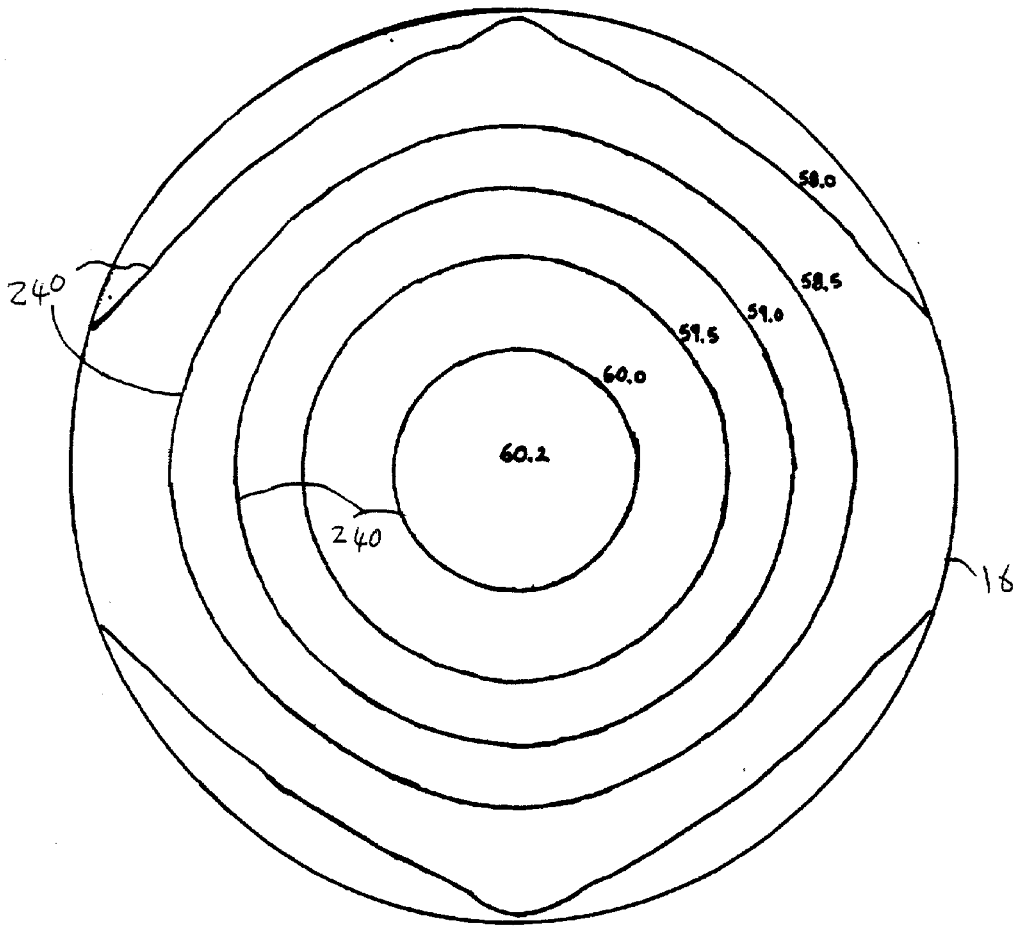


FIG. 15


58.0
58.5
59.0
59.5
60.0
60.2
240
240
16
FIG. 16

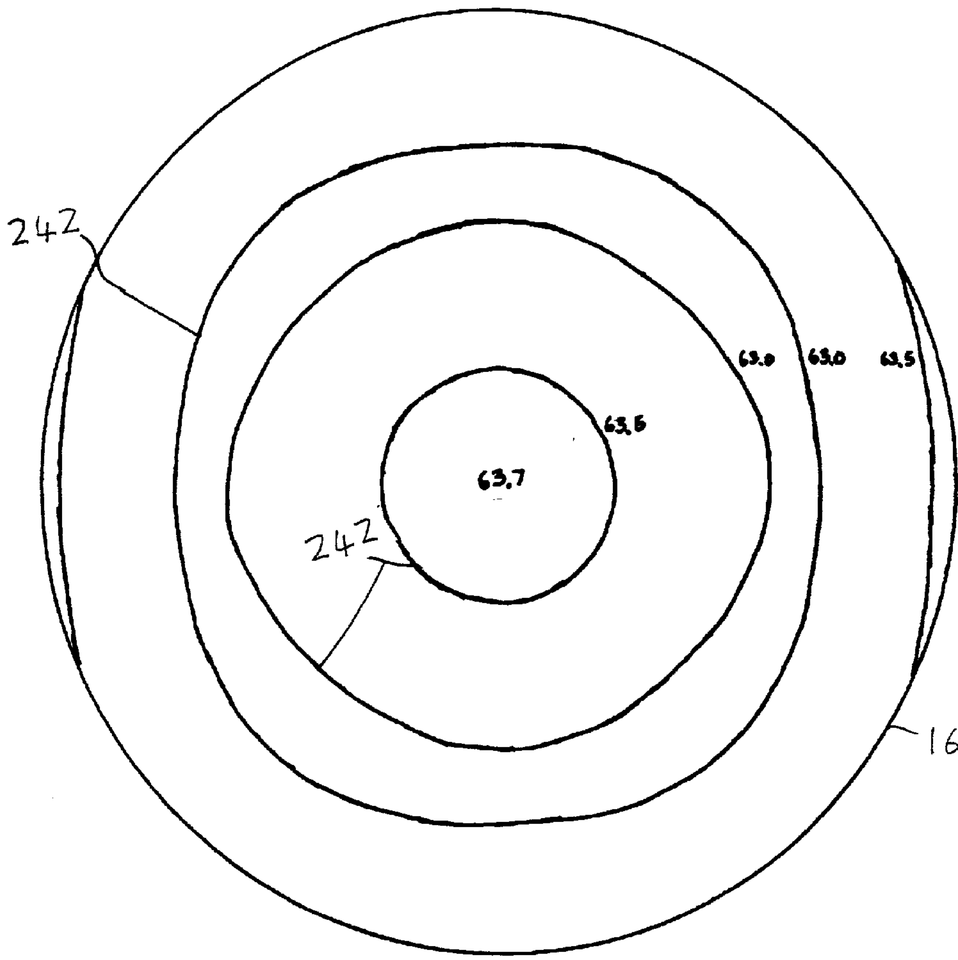


FIG. 17

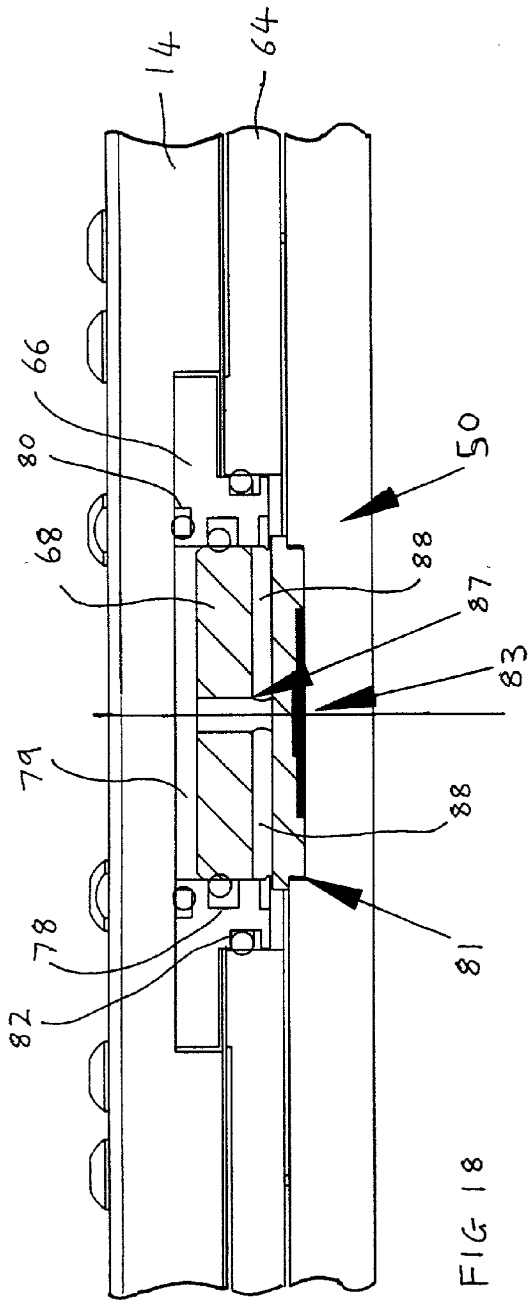


FIG 18

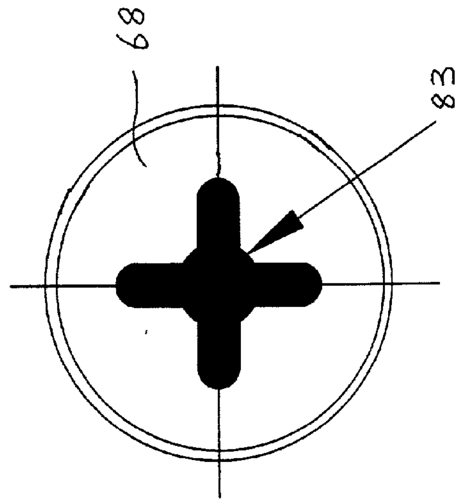


FIG. 19

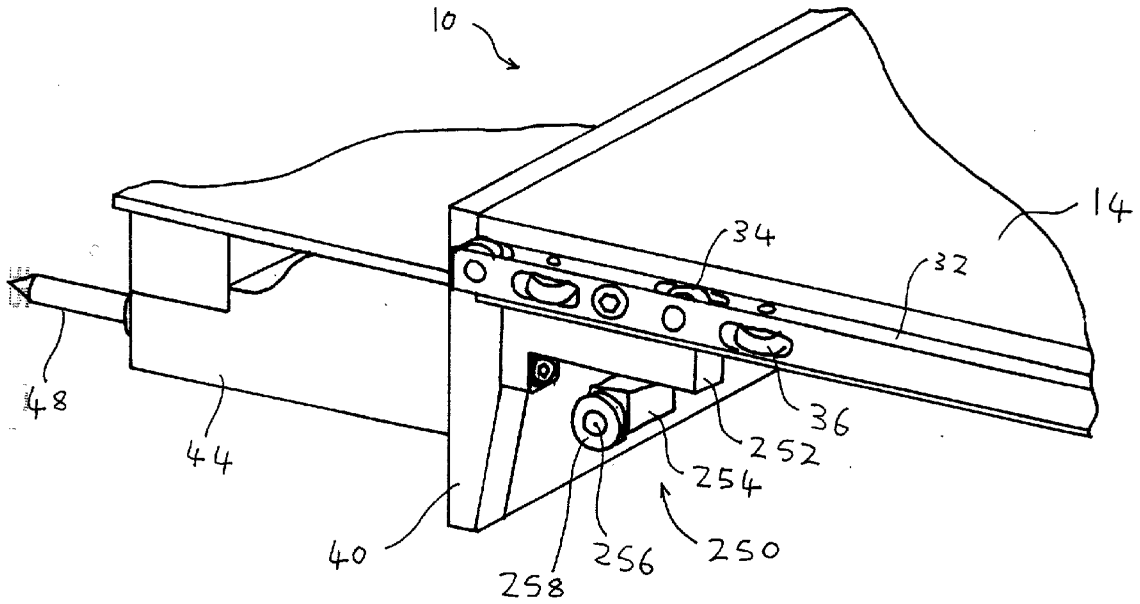


FIG. 20

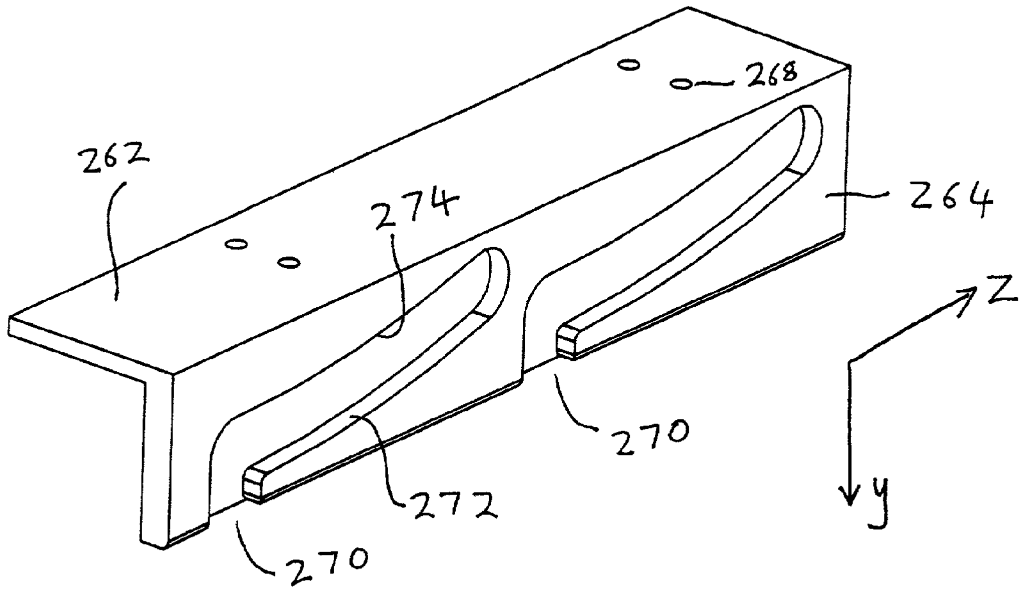


FIG. 21

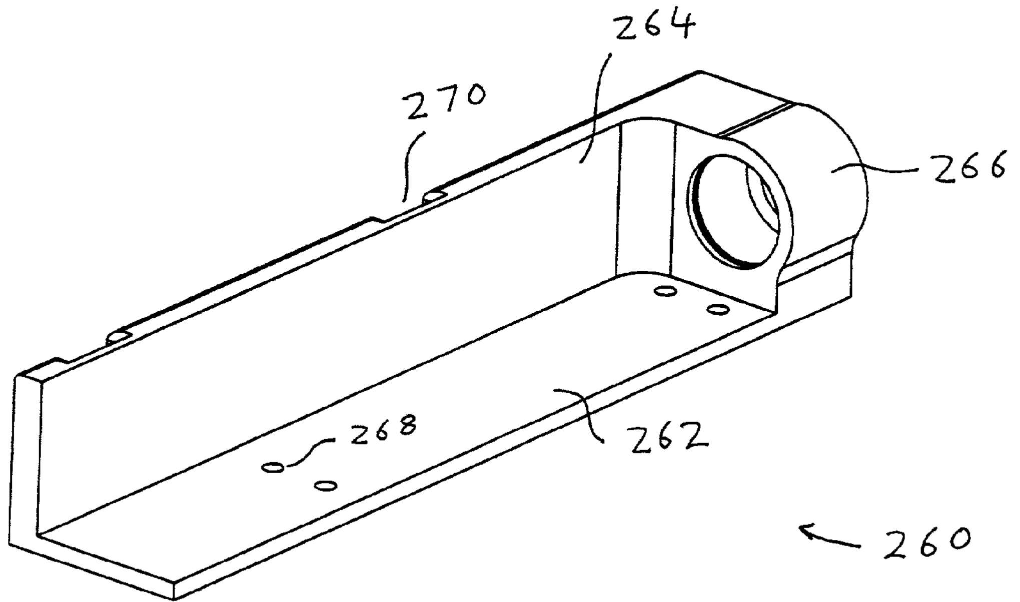


FIG. 22

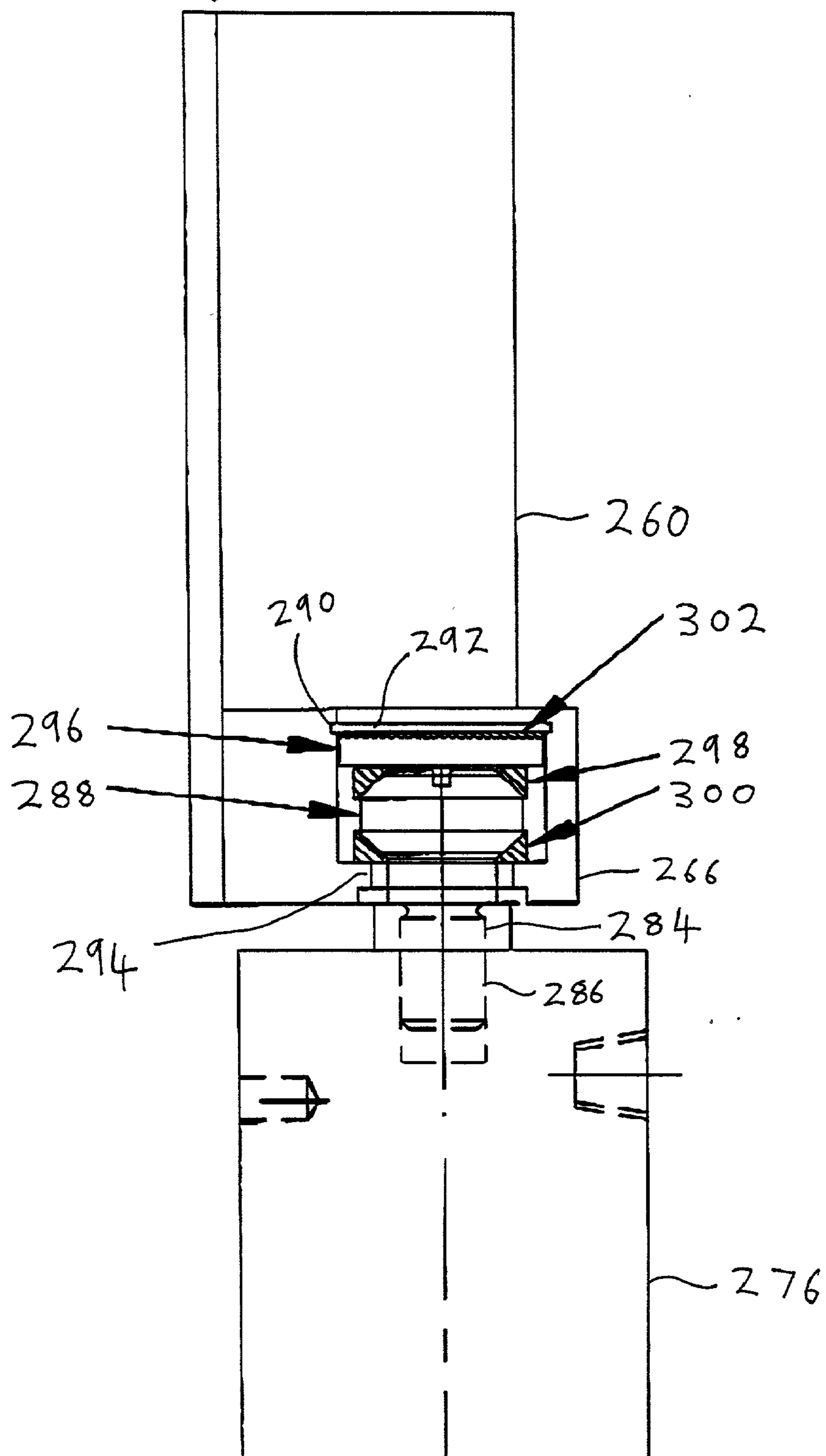


FIG. 23

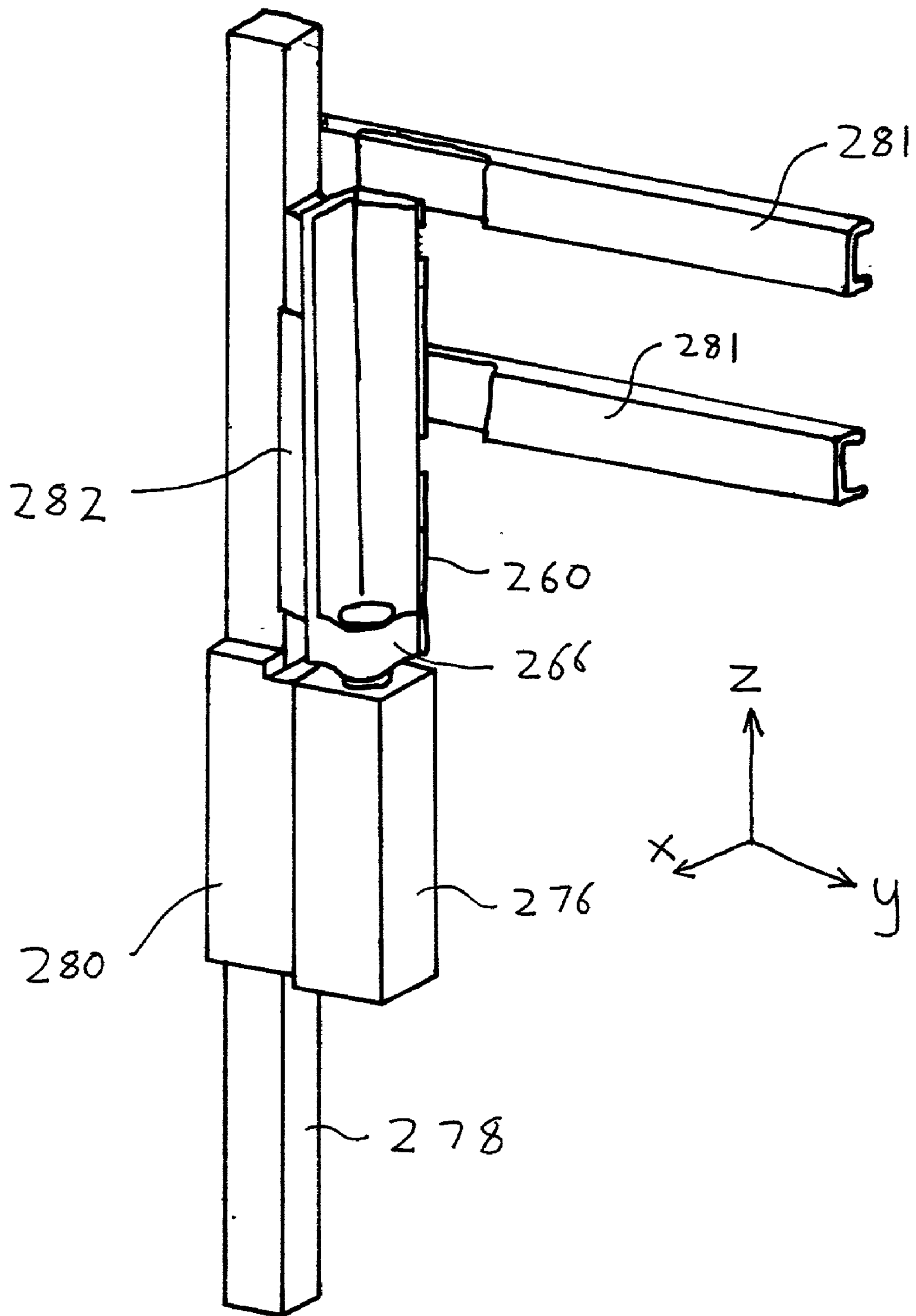


FIG. 24

KINEMATIC COUPLING

[0001] This invention was supported in part by grants from the Defense Advanced Research Projects Agency. The U.S. Government may have rights in this invention.

INTRODUCTION

[0002] 1. Technical Field

[0003] This invention particularly relates to a cartridge for use in the burn-in and/or test of circuitry formed on semiconductor wafers, before the wafer is diced. The invention may however also be applicable to the burn-in or test of other electrical devices. This invention further relates to methods of loading and aligning a probe card in the cartridge with a semiconductor wafer located in the cartridge. The invention also relates to a connecting device for use in the cartridge. This invention is related to the inventions in commonly owned U.S. Pat. No. 5,429,510, issued to Barraclough et al. on Jul. 5, 1995, entitled "High-Density Interconnect Technique," and commonly owned U.S. Pat. No. 5,682,472, issued to Brehm et al. on Oct. 28, 1997 and entitled "Method and System for Testing Memory Programming Devices," the disclosures of which are hereby incorporated by reference herein. This invention is further related to the invention in a concurrently filed, copending, commonly owned application entitled "Wafer Level Burn-In and Electrical Test System and Method" (Attorney Docket No. AEHR-007/00US,) the disclosure of which is also incorporated by reference herein.

[0004] 2. Background of the Invention

[0005] It is well known that integrated circuits (IC's), if they are going to fail, tend to fail early in their projected lives. To identify and eliminate such fragile IC's, IC manufacturers typically expose their integrated circuits to conditions that tend to induce such premature failure. This is known as burn-in, and the typical conditions to which the integrated circuits are exposed during burn-in are elevated temperatures together with the simultaneous application of electrical signals to the integrated circuits. The elevated temperature and the applied signals may exceed normal operating parameters. Once an integrated circuit has passed a test during or after burn-in, the chances of it functioning throughout its intended service life are greatly increased.

[0006] Burn-in may be done at various times. In many cases, burn-in is done when the IC is in its final packaged form. In such a case, the IC is plugged into a circuit board that allows the required electrical signals to be applied to the IC. Burn-in of packaged IC's has the advantage that the packaged IC is much less sensitive to physical damage or contamination, and can easily be plugged into the burn-in circuit board to make the required connections. Disadvantages of burning-in packaged IC's are that the added expense of packaging the IC is lost if the IC fails during burn-in, that there are many more individual components to handle, and that the same die type may end up in a number of different package types requiring different fixtures for burn-in.

[0007] Another burn-in option is to put individual dies into reusable packages, and then burn-in the die in the reusable package in a similar manner to the burn-in of packaged IC's. This method has the advantage that less has been invested in the IC at this time, but has the disadvantage that the individual dies are difficult to handle conveniently, and are susceptible to damage or contamination.

[0008] The cartridge of the invention is used for wafer-level burn-in. That is, the integrated circuit wafer undergoes burn-in before separation into individual dies and traditional packaging. Wafer-level burn-in has the advantages that failure-prone IC's are identified early, that for certain chip types (e.g., DRAM) there is the possibility of laser-repairing burn-in defects, and that wafer maps of burn-in failures are easily generated. Wafer maps assist in identifying and rectifying wafer processing flaws. Wafer-level burn-in has the disadvantages that careful handling of the wafer is required, and that making electrical contact with the wafer is more difficult. An example of a fixture used for wafer-level burn-in is shown in U.S. Pat. No. 5,859,539 to Wood et al.

[0009] IC's also typically undergo functional tests at some point. These tests verify that the IC has the required functionality at the desired speed and accuracy. The functional tests can be used to reject IC's entirely, or may be used to classify IC's into different grades.

[0010] The cartridge of the invention may be used for wafer-level burn-in and/or testing.

SUMMARY OF THE INVENTION

[0011] According to the invention there is provided a method of burning-in or testing a wafer, comprising the steps of placing the wafer on a chuck plate; aligning a probe plate with the wafer; and locking the chuck plate and the probe plate together. Preferably the step of placing the wafer on the chuck plate comprises the step of aligning the wafer with the chuck plate to within a first tolerance and the step of aligning the probe plate with the wafer is done to within a second tolerance, the first tolerance being greater than the second tolerance.

[0012] Also according to the invention there is provided a cartridge for wafer-level burn-in or test, comprising a chuck plate to receive a wafer, a probe plate to establish electrical contact with the wafer, and a mechanical connecting device to lock the chuck plate and the probe plate fixed relative to one another. Preferably, the probe plate includes a probe card movably coupled to the probe plate. More preferably, the probe card is mounted to the probe plate by at least two leaf springs and there is a piston slidably located in a recess formed in the probe plate behind the probe card.

[0013] Yet further according to the invention there is provided a kinematic coupling comprising a male connector including an undercut surface; and first and second opposed jaws. Each of the jaws is movable from a retracted position in which the male connector can be inserted between the jaws and an engaging position in which the jaws prevent withdrawal of the male connector from between the jaws by engaging the undercut surface of the male connector. Preferably the first and second jaws are biased towards their respective engaging positions, and the first and second jaws each include an inclined surface that can be acted upon by a key to move the first and second jaws into their respective retracted positions. More preferably, the male connector is movably coupled to a substrate such that, when the male connector is inserted between the first and second jaws and the first and second jaws are both in their engaging positions, the male connector is movable relative to the substrate between an extended position in which the engaging surface of the male connector is not in contact with the first and second jaws and a retracted position in which the engaging

surface of the male connector is in contact with the first and second jaws. Even more preferably, the male connector is biased towards its retracted position, thereby to provide a positive clamping force.

[**0014**] Still further according to the invention there is provided a wafer level burn-in or test cartridge, comprising:

[**0015**] a first plate;

[**0016**] a second plate;

[**0017**] a male connector that is mounted to the first plate, the male connector including an undercut surface; and

[**0018**] at least one jaw that is movably coupled to the second plate, the jaw being movable from a retracted position in which the male connector can be received by the jaw and an engaging position in which the jaws prevent withdrawal of the male connector from the jaw by engaging the undercut surface of the male connector.

[**0019**] Further details of the invention are set forth in the section entitled: "Description of Specific Embodiments."

BRIEF DESCRIPTION OF THE DRAWINGS

[**0020**] **FIG. 1** is a perspective view of a wafer-level burn-in and test cartridge according to the invention;

[**0021**] **FIG. 2** is a partially cut away and exploded perspective view of the probe plate of the cartridge shown in **FIG. 1**;

[**0022**] **FIGS. 3 and 4** are two views of a leaf spring for use in the cartridge of **FIG. 1**;

[**0023**] **FIG. 5** is a partial cross sectional view through the cartridge of **FIG. 1**;

[**0024**] **FIG. 6** is a cross sectional view of the mechanical connecting device of the cartridge of **FIG. 1**;

[**0025**] **FIG. 7** is a top view of the lower portion of the connecting device of **FIG. 6**;

[**0026**] **FIGS. 8A** to **8D** illustrate the actuation of the mechanical connecting device of **FIGS. 6 and 7**;

[**0027**] **FIG. 9** is a schematic view of the relationship between the male connector and the jaws of the mechanical connecting device of **FIG. 6**.

[**0028**] FIGS. **10** to **12** are plan views of alternative configurations of the jaws of the mechanical connecting device of **FIG. 6**;

[**0029**] **FIG. 13** is a cross-sectional view of the connector end of the probe plate of the cartridge of **FIG. 1**;

[**0030**] **FIG. 14** is a schematic view of the underside of the probe plate of the cartridge of **FIG. 1**;

[**0031**] FIGS. **15** to **17** are plan views of isotherms on the upper surface of the chuck plate pedestal of cartridge of FIGS. **1-3**;

[**0032**] **FIG. 18** is an enlarged cross-sectional partial view of the chuck plate, piston, probe card and related components of the cartridge of **FIG. 1**;

[**0033**] **FIG. 19** is a plan view of the lower surface of the alignment plug of **FIG. 18** to illustrate the shape and size of the epoxy bond between the probe card and the alignment plug;

[**0034**] **FIG. 20** is a perspective view of one corner of the cartridge of **FIG. 1**;

[**0035**] **FIGS. 21 and 22** are perspective views of a cam plate for use with the cartridge of **FIGS. 1 and 20**;

[**0036**] **FIG. 23** is a cross-sectional view illustrating the coupling between the cam plate of **FIGS. 21 and 22** and a pneumatic cylinder; and

[**0037**] **FIG. 24** is a perspective view of a mechanism for engaging and disengaging the electrical connectors of the cartridge of **FIG. 1** with corresponding electrical connectors in a burn-in chamber.

DESCRIPTION OF SPECIFIC EMBODIMENTS

[**0038**] A wafer-level burn-in and test cartridge according to the invention is illustrated in **FIG. 1**. The cartridge, generally indicated by the reference numeral **10**, comprises a chuck plate **12** and a probe plate **14**. The chuck plate **12** and the probe plate **14** may be made of any suitable material. In the illustrated embodiment, the chuck plate **12** and the probe plate **14** are made of 6061 aluminum.

[**0039**] The chuck plate **12** is generally rectangular in shape, and includes a centrally-located raised pedestal **16**. In use, a semiconductor wafer is placed on the upper surface **18** of the pedestal **16**. Mounted to the upper surface of the chuck plate **12** are the lower halves **20** of three mechanical connecting devices that are used to lock the chuck plate **12** and the probe plate **14** together in use. In the illustrated embodiment, the mechanical connecting devices are kinematic couplings, which are discussed below in more detail with reference to FIGS. **6** to **12**. Formed transversely through the chuck plate **12** are a number of channels **22** that have air or another fluid circulated through them in use to cool or heat the chuck plate **12**. Formed around the edges of the chuck plate **12** are a number of handhold recesses **24** that encourage an operator to pick the chuck plate up away from the pedestal **16** or the lower halves **20** of the mechanical connecting devices. The chuck plate **12** may also be provided with vertical holes (usually three) extending between the upper surface of the pedestal and the bottom surface of the chuck plate **12**. Such holes may be used for the insertion of wafer-lift pins that are used in some wafer alignment systems.

[**0040**] The probe plate **14** is also generally rectangular in shape, and also has a number of handhold recesses **26** formed in its upper surface **28** to encourage an operator to pick the probe plate **14** up away from the sensitive areas of the probe plate. Also shown on the upper surface of the probe plate are access covers **30** by means of which access can be gained to the upper halves (not shown) of the mechanical connecting devices.

[**0041**] Also shown on the probe plate **14** are a number of nipples **31**, **33** whereby pneumatic connections can be made to the cartridge **10**. Pneumatic and/or vacuum actuation is used in the operation of various parts of the cartridge as will be described in more detail below. While the actuation

described below is effected by varying the pressure of air, it will be appreciated that other fluids could also be used in the invention.

[0042] Located on each side of the probe plate **14** is a rail **32** (one side shown.). Mounted in each rail are a number of vertically-oriented wheels **34** and a number of horizontally-oriented wheels **36**. The wheels **34, 36** are mounted on shafts **38**, and in the preferred embodiment the wheels are small ball bearings. In use, the rails **32** slide into correspondingly shaped channels in a burn-in chamber, with the vertically-oriented wheels **34** supporting the cartridge **10** on the lower surface of the channels and with the horizontally-oriented wheels preventing the rails **32** from sliding against the sidewalls of the channels. The channels in the burn-in chamber may extend beyond the ends of adjacent inserted cartridges, to further facilitate insertion of the cartridge in the burn-in chamber.

[0043] Located at one end of the probe plate **14** is a vertical flange **40**. Attached to the flange **40** is a connector block **44** that has a number of electrical connectors **46** mounted thereto. In use, the electrical connectors **46** are used to establish electrical connection with the wafer. Mounted to the flange **40** around the connector block **44** is a seal **42**. In use, the cartridge **10** is slid connector-side first into a high temperature section of the burn-in chamber, until the connector block **44** protrudes out of the high-temperature section into a lower temperature section through an aperture in a rear wall of the burn-in chamber. The seal **42** then serves to seal against the wall around the aperture, thereby isolating the connector block from the conditions in the high-temperature section of the burn-in chamber. The connector block **44** is made of a high temperature polymer such as Altem, which is a thermal insulating material that serves to insulate the electrical connectors **46** from the high temperatures to which the flange **40** is exposed in use. Finally, mounted to the connecting block **44** are two alignment pins **48** that serve to align the connectors **46** with corresponding electrical connectors when the cartridge **10** is slid into the burn-in chamber.

[0044] **FIG. 2** shows the underside of the probe plate **14**, as well as a further component of the cartridge, the probe card **50**. The probe card **50** is the part of the cartridge that actually makes direct electrical contact with the wafer during wafer-level burn in and/or test, and the probe card **50** is thus different for each different type of wafer undergoing burn-in and/or test. The probe card **50** is electrically connected to the electrical connectors **46** by means of printed circuit boards as is described in more detail in the concurrently filed, copending, commonly owned patent application entitled: "Wafer Level Burn-in and Electrical Test System and Method" (Attorney Docket Number AEHR-007/00US,) the disclosure of which is incorporated herein by reference.

[0045] The probe card **50** is preferably made of a material that is thermally matched with the semiconductor material from which the wafer is made. That is, when heated, the probe card **50** and a wafer under test will expand by similar amounts. This ensures that the electrical contact between the probe card **50** and a wafer under test is not disturbed as the cartridge is heated in a burn-in chamber. This permits the probe card **50** to be aligned with the wafer when the wafer is at room temperature, before exposure to the elevated temperatures of burn-in. For example, the probe card **50** may be made of made of silicon-carbide, which provides a good thermal match with a silicon wafer. However, it should be noted that the particular details of the probe card **50** do not form part of the invention, and currently available and future-developed probe cards **50** can advantageously be used in the cartridge and methods of the invention. For example, a probe card that is suitable for use in the cartridge and methods of the invention can be purchased from the Electronics Division of W. L. Gore & Associates, Inc. of Delaware.

[0046] The probe card **50** is mounted to the probe plate **14** by means of four leaf springs **52** that are spaced around the perimeter of the probe card **50**. The leaf springs **52** permit relative motion between the probe plate **14** and the mounted probe card **50** along the z-axis (that is, perpendicular to the surface of a wafer located on the pedestal **16**). The leaf springs **50** also permit the probe card to rotate to some degree relative to the probe plate **14** around the x or y-axes (i.e., rotation about perpendicular axes both being parallel to the surface of the wafer). The leaf springs **52** however prevent substantial movement of the probe card **50** relative to the probe plate **14** along the x or y-axes, and also prevent substantial rotation of the probe card **50** relative to the probe plate **14** about the z-axis. Preferably, the leaf springs **52** are spaced about the circumference of the probe card **50** to provide a substantially maximum resistance to rotation of the probe card relative to the probe plate about the z-axis. When the probe card is rectangular as shown, this is accomplished by locating a leaf spring **52** at or near each of the four comers of the probe card **50**.

[0047] This leaf spring mounting arrangement permits the probe card **50** to be moved into and out of contact with a wafer located on the pedestal **16**, and permits the probe card to "settle" evenly onto a wafer if one edge or area of the probe card **50** contacts the wafer first. However, misalignment of the probe card **50** and the wafer is minimized during application of the probe card to the wafer, since the leaf springs **52** resist translation of the probe card **50** across the surface of the wafer and also resist rotation of the probe card **50** around an axis perpendicular to the surface of the wafer.

[0048] One of the leaf springs **52** is shown in more detail in **FIGS. 3 and 4**. As can be seen from **FIG. 4**, the leaf spring **52** has a non-linear profile. More particularly the leaf spring **52** includes a curved central portion **54** in the shape of a channel that extends across the width of the leaf spring **52**. The central portion **54** permits the leaf spring to deform predictably under compression forces F that might otherwise cause the leaf spring **52** to buckle unpredictably. The central portion **54** also ensures that the different leaf springs **52** behave in a substantially uniform manner under tension or compression, providing uniform compliance around the probe card **50**. The predictable compliance of the leaf spring under compression or tension also permits the mounting arrangement to compensate predictably for any changes in dimension resulting from any mismatch of the thermal coefficients of expansion of the probe card and probe plate materials. The leaf spring **52** includes four holes **56** defined therein whereby the leaf spring can be screwed to the probe card and to the probe plate.

[0049] By way of example only, a leaf spring for use in the cartridge of the invention has a width of 0.8" (20.3 mm,) a length of 1.23" (31.2 mm,) a thickness of 0.010" (0.254 mm)

and the central portion **54** has an approximate radius of 0.31" (7.87 mm.). The leaf spring **52** is made of beryllium copper, but may be made of any suitable spring material.

[**0050**] Returning now to **FIG. 2**, it can be seen that the probe plate **14** defines a recess **58** for receiving the probe card **50**. The recess **58** includes four notches for receiving the leaf springs **52**.

[**0051**] Defined in the center of the recess **58** is a cylindrical recess **62** that receives a thin cylindrical piston **64**. Defined in the center of the recess **58** is a further cylindrical recess **65** that has a sleeve **66** mounted therein. When the probe card is mounted to the probe plate **14** with the piston **64** received in the recess **62**, a guide plug **68** mounted on the back of the probe plate **50** is located in the sleeve **65**. The guide plug **68** serves to provide additional alignment and guidance of the probe card **50** as it moves towards and away from the wafer.

[**0052**] The relationship between the probe card **50**, the piston **64** and the probe plate **14** is shown in more detail in **FIGS. 5 and 18**. **FIG. 5** also shows the relationship in use between these components and the chuck plate **12**, having a wafer **74** positioned thereon, and **FIGS. 18 and 19** show how the probe card **50** is mounted to the guide plug **68**.

[**0053**] The probe card **50** is mounted to the guide plug **68** by means of an epoxy bond **83**. The epoxy used is typically a Loctite™ aerobic adhesive. By mounting the probe card **50** at its center using a small area of epoxy **83**, thermal mismatch between the probe card **50** and the rest of the cartridge is minimized, since the probe card **50** is free to expand or contract relative to the rest of the cartridge. To center the probe card **50** relative to the alignment plug **68** during bonding, and to provide a degree of compliance between the alignment plug **68** and the probe card **50**, a strip of Teflon™ tape **81** is provided around the lower circumference of the alignment plug **68**.

[**0054**] As can be seen from the figures, the sleeve **66** has a cylindrical inner bore that receives the guide plug **68**. Formed in the sleeve **66** are three grooves—a groove **78** in the bore **70**, a groove **80** in the upper surface of the sleeve **66** and a groove **82** in the stepped outer surface of the sleeve **70**. These three grooves have O-rings received therein as shown. Similarly, the piston **64** has one groove **84** formed in its edge (circumference) and one groove **85** formed in its lower surface. These grooves in the piston also have O-rings received therein. These five O-rings serve to provide an airtight seal between the space **72** behind the piston and the general vicinity of the wafer. Accordingly, by increasing the air pressure in space **72** behind the piston **64**, the piston (and hence the probe card **50**) can be advanced towards the wafer **74**. Similarly, by reducing the pressure in space **72**, the piston **64** (and hence the probe card **50**) can be retracted from the wafer **74**. This is done via a conduit formed in the probe plate between the space **72** and one of the nipples **31** located on the exterior of the probe plate **14**.

[**0055**] Alternatively, if the pressure in the space **72** is left unchanged, the piston can be moved by varying the pressure in the general vicinity of the wafer **74**, thereby creating a pressure differential between different sides of the piston **64** as before, except reversed in action. That is, by decreasing the air pressure in the general vicinity of the wafer **74**, the piston (and hence the probe card **50**) can be advanced towards the wafer **74**. Similarly, by increasing the pressure in the general vicinity of the wafer **74**, the piston **64** (and hence the probe card **50**) can be partially retracted from the wafer **74**. Manipulation of the air pressure in the vicinity of the wafer **74** is done via a conduit formed in the probe plate **14** that provides fluid communication between one of the nipples **31** and a region **79** behind the guide plug **68** (see **FIG. 18**). The region **79** is in turn in fluid communication with a region between the piston **64** and the probe card **50** via an axial bore **87** and one or more transverse bores **88** formed in the guide plug **68**. The area between the probe card **50** and the piston **64** is in turn in fluid communication with the immediate vicinity of the wafer **74** via a hole **89** formed in the probe card **50**. Thus, when the pressure in the region **79** is reduced, there is a corresponding reduction in the pressure in the vicinity of the wafer **74**. If the piston **64** is to be moved by a reduction of the air pressure in the vicinity of the wafer **74**, an O-ring **75** is provided in an annular groove **76** defined in the upper surface **18** of the pedestal **16**. The probe card **50** abuts the O-ring **75** in the groove **76** to seal the area in the vicinity of the wafer **74**. The use of an O-ring **75** in the groove **76** also assists in maintaining cleanliness of the wafer **74**.

[**0056**] As an alternative to the routing described in the previous paragraph for reducing the pressure in the vicinity of the wafer **74**, the vacuum path may travel for a short distance in the probe plate **14** from the nipple **31** before being transferred to the chuck plate **12** by means of a pneumatic seal. The vacuum would then be conveyed through the chuck plate **12** to the vicinity of the wafer **74** via a passage formed in the chuck plate **12**.

[**0057**] The nipples **31** that are used in the control of the movement of the piston **64** are of the type that close when the pneumatic lines coupled to the nipples **31** are removed. This means that after the probe card **50** is advanced against the wafer **74** with the required probe actuation force, the cartridge can be disconnected from the pneumatic lines, and the required probe actuation force is then maintained independently by the cartridge **10**. This has the advantage that the burn-in of the wafer can be done separately from the expensive equipment required to align the wafer and probe card, and a separate mechanism to provide the probe actuation force is not required. It should be noted however that pneumatic connection with the cartridge **10** is typically reestablished in the burn-in chamber. This permits the various pressure differentials to be maintained (in case of leaks,) and also permits the pressure differentials to be maintained constant as the cartridge is heated or cooled.

[**0058**] The cartridge also includes three mechanical connecting devices **90** as shown in more detail in **FIG. 6**. The connecting devices **90** are used to clamp the chuck plate **12** and the probe plate **14** together. The connecting device **90** comprises a lower portion **20** and an upper portion **92** that are located as shown in **FIGS. 1, 2 and 14**. While the terms "upper" and "lower" are used here for convenience, it will be appreciated that these two portions of the connecting device may be used in any functional orientation.

[**0059**] The upper portion **92** of the connecting device includes a male connector **94**. The male connector **94** includes a head **96** and a neck **98**. At the base of the neck **98**, the male connector defines a cylindrical piston **100** whereby the male connecting device is movably mounted to the

substrate **102**. In the illustrated embodiment, the substrate **102** is the probe plate **14**. Located in a groove **104** defined in the edge of the piston **100** is a seal **106** that serves to seal the interface between the piston **100** and the substrate **102**. Located in an annular groove **108** around the neck **98** of the male connector are several Belleville springs **110**. The head **96** defines an undercut surface **114**, and is mounted to the neck **98** by means of a bolt **112**. On either side of the piston **100** are cover plates **116** and **118** that are mounted to the substrate **102**. The springs **110** bear respectively against the bottom surface of the groove **108** and the cover plate **116**, thereby to bias the male connector **94** into a retracted position. Defined between the piston **100**, the cover plate **118**, and the substrate **102** is a space **118**. The space **118** is connected to the nipples **33** shown in **FIG. 1** via a conduit **120**. By introducing high-pressure air into the space **118** via the conduit **120**, the male connector **94** can be advanced against the bias of the springs **110** into an extended position.

[**0060**] Referring now to **FIGS. 6 and 7**, the lower portion **20** of the mechanical connecting device **90** is seen to include first and second opposed jaws **122, 124**. The jaws **122, 124** are pivotally mounted to the chuck plate by means of pivot pins **126**. This mounting arrangement permits the jaws **122,124** to pivot from a retracted position (shown in **FIG. 6**) in which the male connector **94** can be inserted between the jaws **122, 124**, and an engaging position (shown in **FIG. 8C**) in which the jaws **122, 124** prevent withdrawal of the male connector **94** therefrom by engaging the undercut surface **114** of the male connector **94**. The jaws are biased towards their engaging position by means of two spring plungers **125** that are located in threaded bores **127** formed in an inclined wedge **142**. The spring plungers each have a threaded outer surface that permits them to be selectively positioned in the bores **127**.

[**0061**] The first and second jaws **122, 124** each include an inclined surface **128** that can be acted upon by a key or probe **130** to move the jaws **122, 124** from their engaging positions into their retracted positions. The probe or key **130** includes a spherical head **132**, and is inserted through a hole defined in the chuck plate **12**. The jaws **122, 124** each include a protruding lip **136** that has an undercut surface **138** that engages the undercut surface **114** of the male connector **94** in use. As can be seen in **FIG. 7**, the front surface of the lip has circular notch formed therein so that the head **96** can be received without undue retraction of the jaws **122, 124**.

[**0062**] Surrounding the jaws **122, 124** is an adjustable stop **140**. The adjustable stop **140** is mounted on top of the inclined wedge **142** by means of four screws **144**. The screws **144** pass through slots **146** defined in two flanges **148** that extend from the lower edges of the stop **140**. The wedge **142** is mounted to the chuck plate **12** by means of four bolts **152**. The upper edges of the stop include central raised portions **154** against which a corresponding raised portion **156** of the cover plate **116** abuts when the connecting device **90** is engaged as will be described in more detail below.

[**0063**] An adjusting mechanism **158** is mounted at one end of the wedge **154**. The adjusting mechanism **158** includes an internally threaded barrel **160** and an externally threaded rod **162**. The rod **162** has a hexagonal recess defined therein by means of which an allen wrench can be used to rotate the rod, thereby to advance or retract it. The rod **162** has a groove **164** defined therein that permits one end of the rod to be received by a vertical, T-shaped groove **166** in the stop **140**. To adjust the height of the raised portion **156** above the chuck plate **12**, the screws **144** are loosened and the rod **160** is rotated to advance or retract the stop **140** along the inclined wedge **142**. When the desired adjustment has been made, the screws **144** are retightened. By adjusting the stops **140** of all three lower portions **20** of the mechanical connecting devices **90**, the distance between the chuck plate **12** and probe plate **14** (when they are clamped together) can be varied. Referring to **FIG. 5**, it will be appreciated that this adjustment permits the cartridge to be adapted to probe cards and wafers of different sizes, and also to make fine adjustments to the relationship between the wafer **74** and the probe card **50**.

[**0064**] While the mechanical connecting device **90** has been described as having a configuration that has the male connector **94** normally retracted, and the jaws **122, 124** normally closed, it will be appreciated that this arrangement may be varied to provide a male connector that is normally extended and jaws **122, 124** that are normally open.

[**0065**] The sequence of operation of the mechanical connecting device **90** is shown in **FIGS. 8A** to **8D**. As shown in **FIG. 8A**, the key or probe **130** is advanced between the first and second jaws **122, 124** against the inclined surfaces **128**, thereby to move the jaws **122, 124** from their engaging positions into their retracted positions. The space **118** is pressurized to advance the piston **100** (and hence the male connector **94**) in the direction of the chuck plate **12**. The chuck plate **12** and the probe plate **14** are then moved together to position the head **96** of the male connector between the jaws **122, 124** as shown in **FIG. 8B**. The clearances between the head **96** and the retracted jaws **122, 124** is sufficient to allow lateral misalignment (i.e., in a direction parallel to the surface of the wafer **74**) of the chuck plate **12** and the probe plate **14** in an amount that is greater than the expected variation in the positioning accuracy of the wafer on the chuck plate **12**. In the illustrated embodiment, the connecting mechanisms **90** can be engaged over a range of relative lateral movement of the chuck plate **12** and the probe plate **14** of +/−0.05" (+/−1.27 mm). As will be discussed in more detail below, this permits the wafer **74** to be positioned relatively crudely on the pedestal **16**. Accurate alignment of the probe card **50** with the wafer is then done directly—by aligning the probe plate **14** with the wafer **74**—without having to be concerned about how the probe plate **14** and chuck plate are going to mate. The probe plate **14** and the chuck plate **12** can then be locked together to maintain the alignment between the probe plate **14** and the wafer **74**. Aligning the probe plate **14** directly with the wafer **74** in this manner avoids the buildup of tolerances that would occur if the wafer was aligned indirectly with the probe plate **14** by first aligning it with the chuck plate **12** and then aligning the probe plate **14** with the chuck plate **12**.

[**0066**] Exemplary figures for the tolerance required of the alignment between the wafer **74** and the probe card **50** are the same as those for alternative wafer-level burn-in and test solutions, e.g., +/−0.001" (+/−25 micron) (based on the Gore probe card alignment pad geometry,) +/−0.0005" (+/−2.5 micron) (for NHK pogo pin adapter plate pin placement.). It will however be appreciated that the tolerance required of the alignment between the probe card **50** and the wafer **74** is dependant on the particular type of integrated circuit formed on the wafer, the size and pitch of the contact pads

on the wafer, and the particular probe card being used. As feature sizes decrease in semiconductor device fabrication, the required alignment tolerances will decrease in a corresponding manner. Accordingly, it should be noted that the figures quoted above are only examples used to illustrate the general relationship between the coarse alignment of the wafer on the chuck plate **12** and the fine alignment between the probe card **50** and the wafer **74**.

[**0067**] As can be seen from **FIG. 8**B, the probe or key **130** is then withdrawn from between the jaws **122**, **124**, thereby to permit the jaws **122**, **124** to return to their engaging positions. The space **118** behind the piston **100** is then depressurized and the male connector **94** is retracted under the biasing effect of the springs **110**, as shown in **FIG. 8D**. As the male connector **94** retracts, the undercut surface **114** of the male connector **94** engages the undercut surfaces **138** of the jaws **122**, **124**. This draws the chuck plate **12** and the probe plate **14** together, until the central raised portion **154** of the stop **140** abuts the raised portion **156** of the cover plate **116**. It should be noted that in the engaged position of the mechanical connecting device **90** shown in **FIG. 8**D, the springs **110** are still compressed, which provides a positive clamping force between the chuck plate **12** and the probe plate **14**. In the illustrated embodiment, the clamping force of each mechanical connecting device when fully engaged, as shown in **FIG. 8**D, is between 165 and 230 pounds (735 to 1020 N,) to provide a total clamping force of 500 to 700 pounds (2.2 to 3.1 kN) for the cartridge **10**. When fully engaged, the probe plate **14** and the chuck plate **12** are prevented from separating by this clamping force, and are prevented from translating relative to one another by frictional engagement of the surfaces **154** and **156**. Frictional engagement between the probe card **50** and the wafer **74** also assist in preventing the probe plate **14** and the chuck plate **12** from translating relative to one another.

[**0068**] It should also be noted that the springs **110** also assist in preventing the buildup of undesirable thermal stresses in the clamped cartridge, since the springs **100** permit movement of the male connector **94** in response to any thermally-induced changes of dimension along the longitudinal axis of the male connector **94**.

[**0069**] To disengage the mechanical connecting device, the procedure described above with reference to **FIGS. 8A** to **8**D is executed in reverse.

[**0070**] **FIG. 9** is a schematic representation of the relationship between the jaws **122**, **124** and the male connector **94** when they are engaged as shown in **FIG. 8D**. When engaged, it can be seen that there are clearances "a" and "b" between the neck **98** and the edges of the lips **136**, and clearances "c" and "d" between the outermost edge of the head **96** and the inner surfaces of the jaws **122**, **124**. These clearances permit the jaws **122**, **124** to engage the head **96** undisturbed even when there is variation in the left-right (in **FIG. 9**) positioning of the male connector **94** between the jaws **122**, **124**. Similarly, it will be appreciated that the male connector can be misaligned in a direction perpendicular to the plane of **FIG. 9**, within limits, without affecting the engagement of the jaws **122**, **124** with the head **96**. This permits the connecting mechanisms **90** to be engaged over a range of relative lateral movement of the chuck plate **12** and the probe plate **14**, as discussed above and below. In the illustrated embodiment, the total lateral misalignment of the chuck plate **12** and the probe plate **14** that can be tolerated by the connecting mechanisms **90** is +/−0.05" (+/−1.27 mm).

[**0071**] The lip **136** of the jaws **122**, **124** may have any one of a number of different profiles, examples of which are shown in FIGS. **10** to **12**. As shown in **FIG. 12**, the lip **136** may have a profile that defines a relatively sharp edge **170** for contacting the undercut surface **114** of the male connector **94** along a single line. Alternatively, the lip **136** may have a semi-cylindrical profile **172** as shown in **FIG. 11** that will also provide line contact between the lip **136** and the undercut surface **114** of the male connector **94**. Yet further, the lip **136** may include a spherical protrusion **174** as shown in **FIG. 12** that provides point contact with the undercut surface **114** of the male connector **94**. While these features and shapes have been shown on the jaws **122**, **124**, it will be appreciated that these or similar features or profiles may be provided on the undercut surface **113** of the male connector **94**. Applicants believe that providing line or point contact between the jaws **122**, **124** and the undercut surface **114** of the male connector **94** helps prevent the creation of lateral forces during the engaging process described above with reference to **FIGS. 8A** to **8**D. Lateral forces may cause lateral motion of the probe plate **14** and the chuck plate **12**, potentially resulting in misalignment of the probe plate **14** and the wafer **74**, which is to be avoided.

[**0072**] It should be noted that while the jaws **122**, **124** are pivotally mounted to the chuck plate **12**, there are alternatives to this arrangement. For example, the jaw(s) may comprise sliding members that are movable between two positions in which the male connector respectively can and cannot be retracted. Also, the jaw may take the form of a plate that has a keyhole-shaped aperture therein, the male connector being insertable in the larger part of the aperture, and being prevented from being withdrawn when the plate is moved relative to the male connector **94** to position the neck **98** of the male connector in the smaller part of the aperture. Accordingly, the term "jaw" can be applied to any arrangement that selectively permits the reception and retention of the male connector.

[**0073**] It is also to be noted that the mechanical connecting device **90** is a kinematic coupling. A kinematic coupling provides forces or movements in controlled and predictable directions. The connecting device **90** is designed to provide motion and a clamping force only in the Z-direction (perpendicular to the wafer) during engagement. By providing forces and movement only in the Z-direction, misalignment between the probe plate **14** and the wafer **74** as a result of the actuation of the clamping device is reduced. Aspects of the mechanical connecting device **90** that contribute to its kinematic nature are the fact that the jaws **122**, **124** are pivotally mounted to the chuck plate **12**, the fact that there is line or point contact between the head **96** and the jaws **122**, **124**, the fact that the male connector **94** moves only in the Z-direction, and the fact that transverse motion between the probe plate **14** and the chuck plate **12** is resisted by frictional engagement between two flat surfaces **154**, **156** that are perpendicular to the Z-direction.

[**0074**] As mentioned before with reference to **FIGS. 1 and 2**, the probe card **50** is electrically connected to the electrical connectors **46** by means of two printed circuit boards. **FIGS. 13 and 14** show the configuration of the printed circuit boards and how they are connected to the connectors **46** and the probe card **50**.

[**0075**] **FIG. 13** is a partial longitudinal cross-sectional view through the probe plate **14**, showing the connector block **44**, the connectors **46**, the flange **40** and the seal **42**. As can be seen from the **FIG. 13**, the connectors **46** include

upper connectors **180** and lower connectors **182**. The connectors **180**, **182** are described in more detail in the concurrently filed, copending, commonly owned patent application entitled: "Wafer Level Burn-in and Electrical Test System and Method" (Attorney Docket Number AEHR-007/00US,) the disclosure of which is incorporated herein by reference.

[**0076**] The upper connectors **180** are mounted to the connector block **44** by means of a spacer block **184** and an alignment pin **186**. The alignment pin **186** serves to align the upper connectors **180** with the lower connectors **182**. The single alignment pin **186** is located centrally along the spacer block **184** in a direction transverse to the plane of **FIG. 13**, to accommodate thermal mismatch between the connector block **44** and the spacer block **184**. Additional fasteners (not shown) are provided to hold the connector block **44** and the spacer block **184** together. These additional fasteners are spaced laterally apart from the alignment pin **186**, and preferably allow for some movement between the spacer block **184** and the connector block resulting from temperature fluctuations. An example of an additional fastener that can be used is a small nut and bolt combination that has spring or wave washers at each end to engage the surfaces of the components to be fastened. The spring or wave washers provide a clamping force while permitting some movement during relative motion resulting from thermal mismatches between the connector block **44** and the spacer block **184**.

[**0077**] Each of the connectors **180** is mechanically and electrically connected to a rigid printed circuit board **188** that passes through a slot **190** formed in the flange **40** to the underside of the probe plate **14**. Each of the connectors **182** is mounted to the connector block **44**, and is mechanically and electrically coupled to a bendable printed circuit board **192**. The bendable printed circuit board **192** passes through a slot (not shown) defined between the spacer block **186** and the connector block **44**, and then passes—together with the rigid printed circuit board **188**—through the slot **190** to the underside of the probe plate **14**. The rigid printed circuit board **188** is used to provide signals to and from the wafer under test, and the bendable printed circuit board is used to provide power to the wafer under test.

[**0078**] **FIG. 14** is a schematic view of the underside of the probe plate **14**. As can be seen from the figure, the bendable printed circuit boards **192**, after passing through the flange **40**, extend on either side of the probe card **50** in a generally L-shaped configuration. Located beneath each bendable printed circuit board **192** is the rigid printed circuit board **188** that extends in a similar manner around the probe card **50**. The printed circuit boards are held against the probe plate **14** by means of a number of appropriately positioned screws. Electrical connection with the probe card **50** is made by a number of flexible interconnections **196**. The interconnections **196** are sufficiently flexible to accommodate the movement of the probe card **50** in use.

[**0079**] The manner in which electrical connections are made in and with the cartridge of the invention is described in more detail in the concurrently filed, copending, commonly owned patent application entitled: "Wafer Level Burn-in and Electrical Test System and Method" (Attorney Docket Number AEHR-007/00US,) the disclosure of which is incorporated herein by reference.

[**0080**] Referring again to **FIGS. 1 and 5**, it can be seen that the chuck plate **12** has features specific to its tasks of locating a wafer and proving thermal management of the wafer during burn-in or test. Formed in the chuck plate **12** are a number of channels **22**. When the cartridge **10** is located in use in a burn-in chamber, fluid is ducted through these channels **22** to remove heat dissipated by the wafer during burn-in. The channels **22** may be interrupted and staggered to further promote heat transfer, and may also be interrupted for access to various mechanical features necessary for the operation of the cartridge. As an alternative to forming the channels **22** in the chuck plate **12**, the chuck plate **12** may be placed in contact with a separate plate in the burn-in chamber that has fluid channels formed therein.

[**0081**] The overall size and shape of the chuck plate **12** are determined from wafer size, as well as space considerations in the existing burn-in chamber configuration. In use, a wafer is placed on the upper surface **18** of the pedestal **16**. The upper surface **18** is polished and lapped to a high degree of smoothness and flatness. It also includes vacuum grooves **19** for wafer restraint. This upper surface **18** receives plating or coating appropriate to the type of wafer under test. Protruding into the side of the pedestal **16** (radially) are a number of bores that receive cartridge heaters **21**. These supply heat for some modes of operation, in order to achieve temperature control. A temperature sensor **23** is installed in the chuck near its top surface, to indirectly sense wafer temperature. In addition to these features, additional features specific to achieving temperature uniformity will be discussed below.

[**0082**] Temperature control of the wafer is accomplished as follows. The air from the burn-in chamber is ducted through the channels **22** of the chuck plate **12**, while a powered wafer is pressed against the top surface by the probe card **50**. The chamber is set for a temperature calculated using the characteristics of the chuck plate system and the wafer power dissipation. Fine control of temperature is from heat addition using the aforementioned cartridge heaters **21**. A standard temperature controller is used to supply power to these heaters and, by receiving input from the temperature sensor **23**, the temperature controller provides active, closed loop feedback control of the temperature of the pedestal **16**.

[**0083**] Power to the heaters **21** and the signal from the temperature sensor **23** is also routed through the connectors **46**. From the connectors **46**, electrical connection is passed to contact pads on the chuck plate **12** via pogo pins mounted on the probe plate **14**. From the contact pads, electrical connection is made with the heaters **21** and the temperature sensor via one or more flexible printed circuit boards that wrap around the pedestal **16**.

[**0084**] It will be appreciated that the flow of heat in use, and the resulting temperature profiles in the chuck plate **12** may be less than ideal. In particular, it is desired to have a uniform and flat temperature profile across the upper surface **18** of the pedestal **16** of the chuck plate **12**. The chuck plate **12** is aluminum. Heat conducts through metallic objects very well, but an object designed with mechanical constraints will (in all likelihood) have an unsuitable temperature distribution on the specified surface. Heat conducts (and convects) through air orders of magnitude more poorly than through metals. The embodiment of the chuck plate **12** described herein introduces precisely dimensioned regions of metal removal that change the effective conductivity of the metallic object in certain regions and/or directions, thus

allowing temperature distribution to be decoupled from the chuck plate's exterior physical dimensions and thermal boundary conditions. The result is the ability to tailor the temperature distribution on a given surface to a broad range of functions and/or values.

[**0085**] As mentioned before, the wafer **74** rests on the upper surface **18** of the pedestal **16**, as shown in **FIG. 5**. This surface experiences a heat flux, due to power dissipated by the wafer **74** that rests upon it. The configuration of the chuck plate **12** allows this surface to be more nearly isothermal, even though the outline dimensions thereof were chosen for mechanical reasons.

[**0086**] Thermal management of the chuck plate **12** is assisted by the use of one or more precisely dimensioned grooves parallel to the upper surface **18**, extending around the circumference of the pedestal **16**. As shown in **FIG. 5**, in the illustrated embodiment of the invention, one such groove is provided—a lower groove **198**. It should be noted that an upper groove **200** is also formed in the chuck plate **12**, but this groove is only used for the routing of electrical wiring to and from the cartridge heaters and temperature sensor, and does not contribute to the thermal management of the chuck plate. Heat flowing into the outer regions of the upper surface **18** is forced to travel radially inward by the groove **198**, thus raising the edge temperature (which would naturally be lower than the center). For a properly sized and shaped groove **198**, it is possible to achieve a nearly constant-temperature top surface **18**.

[**0087**] FIGS. **15-17**, showing isothermal lines on the upper surface **18** of the pedestal **16**, are useful for a more complete understanding of the operation of the thermal management features of the cartridge of the invention. **FIG. 15** shows elliptical isothermal lines **238** formed in the upper surface **18** of the pedestal **16** in the absence of thermal management features. The temperature of each isothermal line **240** is shown in ° C. Elliptical isothermal lines typically occur as a result of an aspect ratio effect of the length of the chuck plate **12** (along the channels **22**) to the width of the chuck plate (across the channels **22**.) To turn the elliptical isothermal lines into circular isothermal lines, the depth of the groove **198** may be varied as it passes around the pedestal. Depending on the particular geometry of the chuck plate, the isothermal lines may not be elliptical. **FIG. 16** shows such a case, where the isothermal lines are generally circular. In such a case it is not necessary to vary the depth of the groove **198**. As shown in **FIG. 17**, when the appropriate groove **198** is provided, isothermal lines **242** have an essentially circular shape, and the upper surface becomes essentially isothermal, by raising the temperature adjacent to the outer edge of the pedestal **16**.

[**0088**] In practice, burn-in of integrated circuits is usually carried out at 125-150° C. In one typical cycle, the integrated circuits are heated to 125-150° C. for 6 hours, followed by electrical test for one-half hour at 70° C. During burn-in of a typical dynamic random access memory (DRAM) integrated circuit wafer, electrical signals supplying about 500 watts of power are supplied to the wafer. If the groove **198** is not provided on the thermal chuck, there is approximately a 3 degree variation in the temperature over the surface of the pedestal **16**. With the appropriate groove **198** on the chuck plate **12**, there is less than a one degree variation in the temperature over the surface of the pedestal **16**.

[**0089**] At higher power levels, the temperature variation over the surface of the pedestal **16** is more significant. For example, some logic devices require application of electrical signals producing a power input in excess of 1 kilowatt to the wafer. Certain logic devices require power inputs as high as 1.5 kilowatt. At 1.5 kilowatt of power to the wafer, if the groove **198** is not provided on the chuck plate **12**, there is approximately a 10° C. variation in the temperature over the surface of the pedestal **16** under these conditions. Such a temperature variation is a significant problem. With the groove **198** on the chuck plate **12**, there is only a two-degree variation in the temperature over the surface of the pedestal **16** under these conditions.

[**0090**] In a specific example, for use with an 8 inch (200 mm) semiconductor wafer and length (along the channels **22**) and width (across the channels **22**) of the chuck plate of 18.72 inch (475 mm) and 165 inch (419 mm) respectively, with a pedestal height of 0.865 inch (21.5 mm,) the groove **198** is 0.062 inch (1.57 mm) high and 1.043 inch (26.49 mm) deep. For the illustrated cartridge, Applicants found that the isothermal lines were in fact not elliptical, and it was thus not necessary to vary the depth of the groove **198** as it passes around the pedestal **16**.

[**0091**] Variation of the characteristics of the groove can however be a useful technique for tailoring the shape of the isothermal lines to the particular thermal characteristics of the cartridge system. For example, fluid in the channels **22** is going to rise in temperature as it flows along the channels **22**, as a result of the heat that is being transferred to the fluid. As a result of this increase in temperature, the heat transfer to the fluid is going to be diminished along the length of the channels **22**. This may result in an undesirable temperature gradient forming on the pedestals along the length of the channels **22**. This can be compensated for by making the groove deeper at the entry side of the channels, or by providing additional grooves, or by tailoring the groove in other ways.

[**0092**] The particular characteristics of the groove **198** will vary depending on the particular characteristics and operation of the burn-in system. To determine the parameters of the groove for a particular burn-in system operated in a particular way, a computer-based heat transfer model of the chuck plate is generated, and the heat transfer characteristics of the chuck are modeled. Appropriate characteristics of the chuck plate in the heat transfer model will then be adjusted (e.g., the depth and variation in the depth of the groove) until the model demonstrates acceptable thermal characteristics. At that time, a prototype will be built and tested in the lab to verify the computer-based model. If the prototype demonstrates acceptable thermal characteristics, the geometry of the prototype will be adopted. If not, further adjustments will be made to the thermal model and the prototype, or just the prototype, until acceptable thermal characteristics are demonstrated by the prototype.

[**0093**] The chuck plate **12** is fabricated from a high thermal conductivity material, such as aluminum or other suitable metal or other material. It may either be integrally formed by machining a single piece of the material or assembled by fastening separate pieces of the material together to give the configuration shown. Preferably the chuck plate **12** is formed integrally, since the absence of interfaces between sub-components increases the efficiency

of the heat transfer between the upper surface **18** of the chuck plate **12** and the fluid in the channels **22**. In particular, this permits air to be used as a heat transfer fluid in the channels **22** at a higher wafer power dissipation level than would otherwise be possible, before requiring the use of a liquid coolant. The use of a gas coolant is more convenient than the use of a liquid coolant.

[**0094**] The loading of a wafer into the cartridge **10** will now be described. Firstly, the chuck plate **12** and the probe plate **14** are put into an alignment system. The alignment system will include appropriate pneumatic or vacuum connections for supplying pressurized air or suction to accomplish movement of the pistons **64** and **100**, and to retain the wafer **74** on the pedestal **16**.

[**0095**] Once the chuck plate **12** has been inserted in the alignment system, wafer **74** is placed on the upper surface of the pedestal. The positioning of the wafer on the pedestal can be done relatively crudely (e.g. within a tolerance of +/−0.005" (+/−0.127 mm) since the ability of the mechanical connecting devices **90** to accommodate misalignment between the probe plate **14** and the chuck plate **12** permits the fine alignment of the probe plate **50** to be done with reference directly to the wafer, without having to worry about precise alignment of the probe plate **14** with the chuck plate **12**. The positioning of the wafer **74** on the pedestal **16** can be done using a known automatic wafer prealignment device that typically includes robot arms and a center and notch or flat finder. The prealignment device aligns the wafer **74** on the pedestal **16** in both x and y directions, and rotationally (theta) using a notch or flat in the wafer. Alternatively, alignment of the wafer on the chuck can be accomplished using a known manual alignment fixture.

[**0096**] Once the wafer **74** has been placed on the upper surface **18** of the pedestal **16**, a vacuum is supplied to the grooves **19** underneath the wafer **74**, thereby to retain the wafer securely on the pedestal **16**. The air pressure in the space **72** behind the piston **64** is also reduced, retracting the piston **64** and the probe card **50** away from the wafer **74**.

[**0097**] A vision capture system then captures images of the wafer and of the probe card, and calculations are performed by the alignment system to determine what movements are required to align the probe card **50** and the wafer **74**. The precise alignment of the probe card **50** and the wafer **74** is then done. This can either be done by movement of either the probe plate **14** or the chuck plate **12**, or by repositioning the wafer using wafer lift pins extending through holes formed in the chuck plate.

[**0098**] As an alternative, it is possible to capture an image of the wafer **74** while it is being held by a wafer handling robot, and then to position the wafer **74** onto the pedestal **16** in the correct alignment with the probe card **50**. In such a case, the alignment and placing of the wafer **74** take place in one step. However, in this case the precise alignment of the wafer is still being done with reference to the probe card **50**/probe plate **14**, and not with reference to the chuck plate **12**.

[**0099**] After the probe card **50** (and hence the probe plate **50**) has been aligned with the wafer **74**, the jaws **122, 124** of the mechanical connecting devices **90** are moved into their retracted positions by advancing the probe or key **130** between the jaws **122, 124** as described above with reference to **FIG. 8**. The space **118** is pressurized to advance the piston **100** (and hence the male connector **94**) in the direction of the chuck plate **12**. The chuck plate **12** and the probe plate **14** are then moved together by the alignment device. This movement is done, as far as is possible, in the Z-direction only, so that the alignment of the probe card **50** and the wafer is not disturbed. The probe plate **14** and the chuck plate **12** are moved together until the heads **96** of the male connectors **94** of the three mechanical connecting devices **90** are positioned between the jaws **122, 124** as shown in **FIG. 8B**.

[**0100**] The probe or key **130** is then withdrawn from between the jaws **122, 124**, thereby to permit the jaws **122, 124** to return to their engaging positions. The space **118** behind the piston **100** is then depressurized and the male connector **94** is retracted under the biasing effect of the springs **110**. As the male connector **94** retracts, it engages the jaws **122, 124**, thereby to draw and lock the chuck plate **12** and the probe plate **14** firmly together, with the central raised portion **154** of the stop **140** abutting the raised portion **156** of the cover plate **116**.

[**0101**] After actuation of the mechanical connecting devices **90**, the piston **64** may be advanced to press the robe card **50** against the wafer **74**. Alternatively, the piston **64** may be advanced or retracted (or, more correctly, the pressure differential across the piston **64** is varied) to adjust the initial probe actuation force. Actuation of the piston **64** is done by creating a pressure differential in the cartridge **10**, which can be done in one of two ways.

[**0102**] Firstly, the pressure in the space **72** can be steadily increased, thereby to advance the probe card **50** against the wafer **74**. The maximum pressure in the space **74** is selected to provide the desired probe actuation force. The desired probe actuation force is wafer and probe card specific, but is typically approximately 500 pounds (2.2 kN) for an 8 inch (200 mm) wafer.

[**0103**] Secondly, the air pressure in the space **74** can be normalized to ambient pressure before or at the same time as the air pressure in the vicinity of the wafer is reduced. In such a case, a seal is provided in the groove **76** as described above. By reducing the pressure in the vicinity of the wafer **74**, the piston **64** and probe card **50** are sucked down onto the wafer. Again, the amount of pressure reduction in the vicinity of the wafer (or more correctly, the pressure differential across the piston **64**) is selected to provide the desired probe actuation forces.

[**0104**] While reducing pressure in the vicinity of the wafer **74** and increasing the pressure in the space **72** are acceptable alternatives for actuating the piston **64**, Applicants believe that reducing the pressure in the vicinity of the wafer is the best mode of providing the probe actuation force, since the reaction forces generated thereby are self-contained at the wafer, probe card **50** and pedestal **16**. This is in contrast to raising the pressure in space **72**, which tends to push the probe plate **14** and chuck plate **12** apart when the probe card **50** bears against the wafer **74**. This would cause some deflection of the probe and chuck plates.

[**0105**] There are a number of more specific methods of locking the chuck plate **12** and the probe plate **14** together and providing a probe actuation force, as will be discussed below. For purposes of conciseness, the stop **140** (with its central raised portion **154**) and the raised portion **156** of the cover plate **116** will now be referred to collectively as "the stops," having a combined "stop height."

[**0106**] Method 1: The alignment device moves the chuck plate **12** and the probe plate **14** together until the probe card **50** comes into contact with the wafer and the stops are bottomed, with the stop height having been adjusted such

that, when the stops are bottomed, the probe card **50** is pressed against the wafer **74** with the full probe actuation force. The alignment device thus provides the entire probe actuation force. This "mechanical only" form of actuation is not preferred since the alignment device is required to provide the probe actuation force, which may be in the range of 100 to 1000 pounds, and is typically about 500 pounds.

[**0107**] Method 2: The alignment device moves the chuck plate **12** and the probe plate **14** together until the probe card **50** comes into contact with the wafer, and the movement of the alignment device is stopped before the stops are bottomed. Again, the stop height has been adjusted such that, when the stops are bottomed, the probe card **50** is pressed against the wafer **74** with the full probe actuation force. The mechanical connecting devices **90** are then actuated to complete the actuation of the cartridge and to provide the entire probe actuation force. In this method, the alignment device is only required to provide a percentage of the probe actuation force. (for example, but not limited to, 1 to 10%,) to lock in the x and y relationships between the probe card **50** and the wafer during final z-movement of the chuck plate **12** and probe plate **14**. Locking in these relationships reduces the chance of misalignment during final actuation.

[**0108**] Methods 1 and 2 are "mechanical only" methods of actuation that have the advantages that a) the probe card **50** is not required to be movably mounted to the probe plate and b) pneumatics/vacuum is not required to provide the probe actuation force. These "mechanical only" actuation methods are thus cheaper to implement than some of the other methods.

[**0109**] Method 3: The alignment device moves the chuck plate **12** and the probe plate **14** together until the probe card **50** comes into contact with the wafer, and the movement of the alignment device is stopped before the stops are bottomed. The mechanical connecting devices **90** are then actuated to bottom the stops. The area **72** behind the piston **64** is then pressurized to provide the probe actuation force. In this method, the alignment device is again only required to provide a percentage of the probe actuation force (for example, but not limited to, 1 to 10%,) to lock in the x and y relationships between the probe card **50** and the wafer during final z-movement of the chuck plate **12** and probe plate **14**.

[**0110**] Method 4: The alignment device moves the chuck plate **12** and the probe plate **14** together until the probe card **50** comes into contact with the wafer and the stops are bottomed. The mechanical connecting devices **90** are then actuated to lock the chuck plate **12** and the probe plate **14** together. The area **72** behind the piston **64** is then pressurized to provide the probe actuation force. In this method, the alignment device is again only required to provide a percentage of the probe actuation force (for example, but not limited to, 1 to 10%,) to lock in the x and y relationships between the probe card **50** and the wafer during final z-movement of the chuck plate **12** and probe plate **14**.

[**0111**] Method 5:The alignment device moves the chuck plate **12** and the probe plate **14** together until the probe card **50** comes into contact with the wafer, and the movement of the alignment device is stopped before the stops are bottomed. The mechanical connecting devices **90** are then actuated to bottom the stops. The pressure in the vicinity of the wafer **74** is reduced to provide the probe actuation force. In this method, the alignment device is again only required to provide a percentage of the probe actuation force (for example, but not limited to, 1 to 10%,) to lock in the x and y relationships between the probe card **50** and the wafer during final z-movement of the chuck plate **12** and probe plate **14**.

[**0112**] Method 6: The alignment device moves the chuck plate **12** and the probe plate **14** together until the probe card **50** comes into contact with the wafer and the stops are bottomed. The mechanical connecting devices **90** are then actuated to lock the chuck plate **12** and the probe plate **14** together. The pressure in the vicinity of the wafer **74** is reduced to provide the probe actuation force. In this method, the alignment device is again only required to provide a percentage of the probe actuation force (for example, but not limited to, 1 to 10%,) to lock in the x and y relationships between the probe card **50** and the wafer during final z-movement of the chuck plate **12** and probe plate **14**.

[**0113**] Applicants believe that methods **5** and **6** are the two, equally good, best-mode methods of locking the chuck plate **12** and the probe plate **14** together and providing a probe actuation force.

[**0114**] Method 7: The alignment device moves the chuck plate **12** and the probe plate **14** together until the stops are bottomed but without the probe card **50** coming into contact with the wafer. The mechanical connecting devices **90** are then actuated to lock the chuck plate **12** and the probe plate **14** together. The area **72** behind the piston **64** is then pressurized to provide the probe actuation force.

[**0115**] Method 8: The alignment device moves the chuck plate **12** and the probe plate **14** together until the stops are bottomed but without the probe card **50** coming into contact with the wafer. The mechanical connecting devices **90** are then actuated to lock the chuck plate **12** and the probe plate **14** together. The pressure in the vicinity of the wafer **74** is reduced to advance the probe card **50** and to provide the probe actuation force.

[**0116**] When the mechanical connecting devices **90** draw the chuck plate **12** and the probe plate **14** together to bottom the stops, appropriate control elements are used to slow the rate of the clamping. The control elements may for example be orifices that are added to the pneumatic lines to slow the rate of venting.

[**0117**] Also, for the methods utilizing a pressure differential to provide or maintain the probe actuation force, the cartridge **10** includes an automatic valve in the appropriate nipple **31** for maintaining the pressure differential when disconnected, thereby to maintain the probe actuation force.

[**0118**] After the execution of one of the above methods, the cartridge is a self-contained and aligned probing and clamping device. The alignment of the wafer and the probe card is maintained as a result of the pressure differential across the piston **64** and/or the clamping force of the mechanical connecting devices **90**. Accordingly, no further external alignment devices are required, and no external mechanism is required for providing a clamping force or a probe actuation force during burn-in. However, upon insertion into a burn-in chamber, connection is typically reestablished with the nipples **31** to provide maintenance of the pressure differential across the piston **64**. This is done to compensate for any leaks that might occur, and also to provide a means for controlling the probe actuation force, since the pressure differentials in the cartridge **10** will vary as the temperature of the cartridge **10** varies.

[0119] To provide the burn-in and/or test of the wafer, the cartridge **10** is placed in a burn-in chamber. The burn-in chamber typically includes a number of horizontally spaced positions for receiving cartridges in a spaced-apart stacked relationship. This permits burn-in of a number of wafers to be done simultaneously.

[0120] To provide the burn-in and test of the wafer, it is necessary to engage the connectors **46**, **180**, **182** with corresponding connectors in the burn-in chamber. To accomplish this engagement, a substantial insertion force may be required. The cartridge **10** and the burn-in chamber include an insertion mechanism, whereby engagement of the respective electrical connectors may be accomplished automatically, as discussed below with reference to FIGS. **20** to **24**.

[0121] The insertion mechanism includes a cam follower arrangement **250**, one of which is provided on each side of the cartridge **10** as can be seen in **FIG. 20**. The cam follower arrangement includes a mounting block **252** mounted to the probe plate **14** adjacent to the flange **40**. The mounting block **252** includes a transversely extending portion **254** and a short shaft **256**. Press-fitted to the shaft **256** is a ball-bearing **258**.

[0122] The outer surface of the ball-bearing **258** is engaged in use by a cam plate **260** that is shown in more detail in **FIGS. 21 and 22**.

[0123] The cam plate **260** includes two walls **262** and **264** that are located at right angles to one another. Between the walls **262**, **264** at one end of the cam plate **258** is a collar **266** whereby the cam plate is connected to a pneumatic cylinder as will be discussed in more detail below. Formed in the wall **262** are four holes **268** by means of which the cam plate may be mounted to a linear slide such as a cross roller bearing slide or a linear ball slide, also as discussed in more detail below. Formed in the outer surface of the wall **264** is at least one groove **270** that is sized to receive the ball bearing **258** of a cartridge **10**.

[0124] In the illustrated embodiment there are two grooves **270**, but of course it will be appreciated that the number of grooves **270** in the cam plate **260** may be varied to accommodate a different number of cartridges **10**. Applicants believe that a single cam plate **260** can comfortably be provided with seven grooves, to enable seven cartridges to be engaged simultaneously with their corresponding electrical connectors in a burn-in chamber.

[0125] Each groove **270** is defined by two cam surfaces **272** and **274**. The cam surface **272** is used to advance the cartridge **10** into the burn-in chamber, thereby to engage the electrical connectors of the cartridge with the corresponding connectors in the burn-in chamber. The cam surface **274** is used to retract the cartridge **10** to disengage the connectors. For a maximum movement of 2.5 inch (64 mm) of the cam plate **260** in the Z-direction, a ball bearing located in the groove (and constrained to move in the Y-direction) will move approximately 0.35 inch (9 mm,) to provide a mechanical advantage of approximately 7. That is, a force applied to the cam plate **264** in the Z-direction will result in a force seven times as large being applied to the ball bearing in the y direction.

[0126] Referring now to **FIGS. 23 and 24**, in use the cam plate **260** is connected in the burn-in chamber to a pneumatic cylinder **276** via the collar **266**. The pneumatic cylinder **276** is in turn mounted to a vertical bar **278** in the burn-in chamber via a connecting block **280**. The pneumatic cylinder has a stroke of approximately 2.5" and is used to move the cam plate in the Z-direction. The cam plate **260** is slidably mounted to the bar **278** by means of a linear slide **282** that transfers lateral forces experienced by the cam plate **260** to the bar **278** while permitting the cam plate to slide along the bar **278** in the Z-direction. Mounted to the bar **278** is at least one channel **281** for receiving the rail **32** of a cartridge **10**.

[0127] The connection between the collar **266** of the cam plate **260** and the pneumatic cylinder **276** is shown in more detail in **FIG. 23**. Screwed into the piston of the pneumatic cylinder **276** is a stud **284**. The stud **284** has screw threads **286** defined in one end thereof for threaded engagement with a bore formed in the piston of the pneumatic cylinder **276**. At the other end, the stud **284** has a beveled head **288**. The collar **266** includes a groove **290** for receiving a retaining ring **292**. The collar **266** also includes an internal ring **294**. In assembled form, the collar also receives a washer **296**, two opposed beveled washers **298** and **300**, and a spring washer **302**. In use, when the piston of the pneumatic cylinder is advanced, the head **288** of the stud **284** bears against the beveled washer **298**. The beveled washer **298** in turn bears against the washer **296**, which bears against the spring washer **302**, which bears against the retaining ring **292**, which in turn transfers the actuating force of the pneumatic cylinder to the collar **266**. When the piston of the pneumatic cylinder is retracted, the beveled head **288** bears against the beveled washer **300**, which transfers the actuating force of the pneumatic cylinder **276** to the collar **266**. The components illustrated in **FIG. 23** fit reasonably snugly together, with the spring washer providing sufficient play to allow some nutational misalignment between the stud **284** and the collar **266**, and the clearances between the outer surfaces of the washers **298**, **300** providing sufficient play to allow some sideways misalignment of the stud **286** and the collar **266**.

[0128] It will be appreciated that **FIG. 24** shows only one half of the structures and components required to support and engage the two sides of a cartridge **10** in the burn-in chamber. A second set of identical, but mirror-image components is provided in the burn in chamber for receiving and engaging the other side of a cartridge **10**.

[0129] In use, the cartridge **10** is slid horizontally, electrical connector end first, into the burn-in chamber, with the rails **32** fitting into the channels **281** in the burn-in chamber. As the cartridge approaches its fully inserted position, the alignment pins **48** enter corresponding alignment holes in the burn-in chamber. This serves to align the connectors **46** with complementary electrical connectors provided in the burn-in chamber. At this time, the ball bearings **258** are received in the open ends of the grooves of two opposed cam plates **260**. The pistons of the pneumatic cylinders **276** are then advanced to provide the necessary forces (via the cam plates **260**) for engaging the electrical connectors **46** on the cartridge with corresponding electrical connectors in the burn-in chamber. As mentioned previously, when engaged, the connectors **46** protrude into a cooler section of the burn-in chamber through an aperture formed in a wall in the burn-in chamber. When the cartridge is fully inserted into the burn-in chamber, the flange **40** and seal **42** serve to close the aperture and isolate the cooler section (and hence the connectors **46**) from the hotter section of the burn-in chamber. Further, when the cartridge is fully inserted in the burn-in chamber, the channels **22** of the cartridge **10** are aligned with air vents for providing cooling air, and external power and test signals can be applied to the wafer **74** via the connectors **46**. Burn-in and test of the wafer then progresses

as described in more detail in the concurrently filed, copending, commonly owned patent application entitled: "Wafer Level Burn-in and Electrical Test System and Method" (Attorney Docket Number AEHR-007/00US,) the disclosure of which is incorporated herein by reference.

[0130] Generally speaking, the temperature in the burn-in chamber is raised to the required temperature, and power and timing, logic or other test signals are applied to the wafer for the required burn-in duration. It will be noted however, that the cartridge may be used for other wafer-level testing or burn-in methods. At the end of the burn-in and/or test procedure, the pistons of the pneumatic cylinders **276** are withdrawn, to disengage the electrical connectors **46** from the electrical connectors in the burn-in chamber. The cartridge **10** is then removed from the burn-in chamber and placed in the alignment device (or a custom fixture), and the wafer is then removed by retracting the piston **64** (and hence the probe card **50**) from the wafer, then disengaging the mechanical connecting devices **90** and then lifting the probe plate **14** off the chuck plate **12** using the alignment device. A wafer-handling robot then removes the wafer. In the cases where the probe card **50** is not movable, it may be necessary for the alignment device or fixture to apply a compressive force to the cartridge **10** before the mechanical connecting devices are disengaged.

[0131] All publications and patent applications mentioned in this specification are herein incorporated by reference to the same extent as if each individual publication or patent application was specifically and individually indicated to be incorporated by reference. The invention now being fully described, it will be apparent to one of ordinary skill in the art that many changes and modifications can be made thereto without departing from the spirit or scope of the appended claims.

What is claimed is:

1. A kinematic coupling comprising:

a male connector including an undercut surface; and

first and second opposed jaws, each of the jaws being movable from a retracted position in which the male connector can be inserted between the jaws and an engaging position in which the jaws prevent withdrawal of the male connector from between the jaws by engaging the undercut surface of the male connector.

2. A kinematic coupling according to claim 1, wherein the first and second jaws are biased towards their respective engaging positions.

3. A kinematic coupling according to claim 2, wherein the first and second jaws each include an inclined surface that can be acted upon by a key to move the first and second jaws into their respective retracted positions.

4. A kinematic coupling according to claim 1, wherein

the male connector is movably coupled to a substrate, and

wherein, when the male connector is inserted between the first and second jaws and the first and second jaws are both in their engaging positions, the male connector is movable relative to the substrate between an extended position in which the engaging surface of the male connector is not in contact with the first and second jaws and a retracted position in which the engaging surface of the male connector is in contact with the first and second jaws.

5. A kinematic coupling according to claim 4, wherein the male connector is biased towards its retracted position.

6. A kinematic coupling according to claim 4 wherein the male connector is moved into its extended position in use by means of a pressure differential.

7. A kinematic coupling according to claim 3 wherein the first and second jaws make line contact with the engaging surface of the male connector in use.

8. A kinematic coupling according to claim 3 wherein the first and second jaws make point contact with the engaging surface of the male connector in use.

9. A kinematic coupling according to claim 3 further comprising

a first stop adjacent to the male connector; and

a second stop adjacent to the jaws, wherein movement of the male connector towards its retracted position in use engages the jaws and pulls the first and second stops together.

10. A kinematic coupling according to claim 9 wherein at least one of the stops is adjustable in the direction of movement of the male connector.

11. A kinematic coupling comprising:

a male connector including an undercut surface; and

at least one jaw, the at least one jaw being movable from a retracted position in which the male connector can received by the at least one jaw an engaging position in which the at least one jaw prevents withdrawal of the male connector from the at least one jaw by engaging the undercut surface of the male connector.

12. A kinematic coupling according to claim 11, wherein

the male connector is movably coupled to a substrate, and wherein in use

the male connector is movable relative to the substrate between an extended position in which the engaging surface of the male connector is not in contact with the at least one jaw and a retracted position in which the engaging surface of the male connector is in contact with the at least one jaw.

13. A kinematic coupling according to claim 12, wherein the male connector is biased towards its retracted position.

14. A kinematic coupling according to claim 12 wherein the male connector is moved into its extended position in use by means of a pressure differential.

15. A kinematic coupling according to claim 12 wherein the male connector makes line contact with the at least one jaw.

16. A kinematic coupling according to claim 12 wherein the male connector makes point contact with the at least one jaw.

17. A kinematic coupling according to claim 12 further comprising

a first stop adjacent to the male connector; and

a second stop adjacent to the at least one jaw, wherein movement of the male connector towards its retracted position in use engages the at least one jaw and pulls the first and second stops together.

18. A kinematic coupling according to claim 17 wherein at least one of the stops is adjustable in the direction of movement of the male connector.

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