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[54] **INTERFACE APPARATUS FOR AUTOMATIC TEST EQUIPMENT**

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[22] Filed: **Sep. 29, 1997**

Related U.S. Application Data

[60] Continuation of application No. 08/754,581, Nov. 21, 1996, abandoned, which is a division of application No. 08/463, 227, Jun. 5, 1995, abandoned, which is a division of application No. 08/299,831, Sep. 1, 1994, abandoned.

[51] **Int. Cl.**[7] **G01R 31/02**

[52] **U.S. Cl.** **324/758**; 324/754; 324/755; 324/765

[58] **Field of Search** 324/754, 755, 324/758, 765, 757

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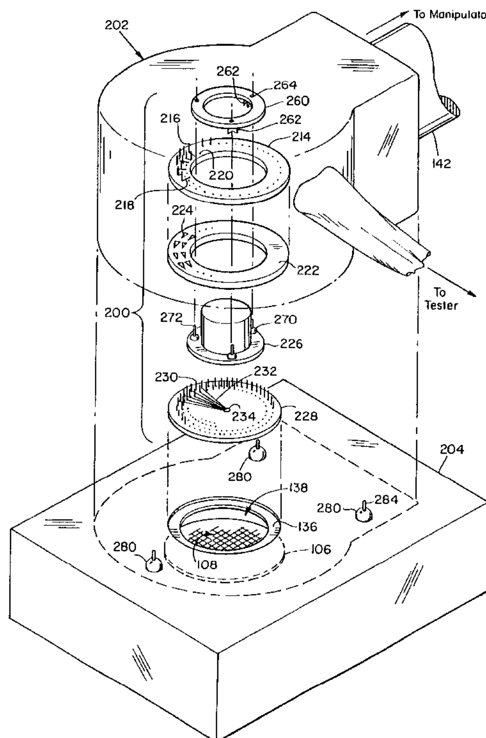
[57] **ABSTRACT**

An interface between a test head portion of automatic test equipment and handling device such as a prober. The interface employs preloaded kinematic couplings between the test head and handling device and between the probe card and the test head. These couplings allow the probe card to be repeatedly positioned relative to the component in the handling device. They also reduce forces on the probe card to prevent distortion of the probe card. The interface provide seperate mechanical and electrical loops such that mechanical position is not dependant on the electrical structure.

20 Claims, 6 Drawing Sheets



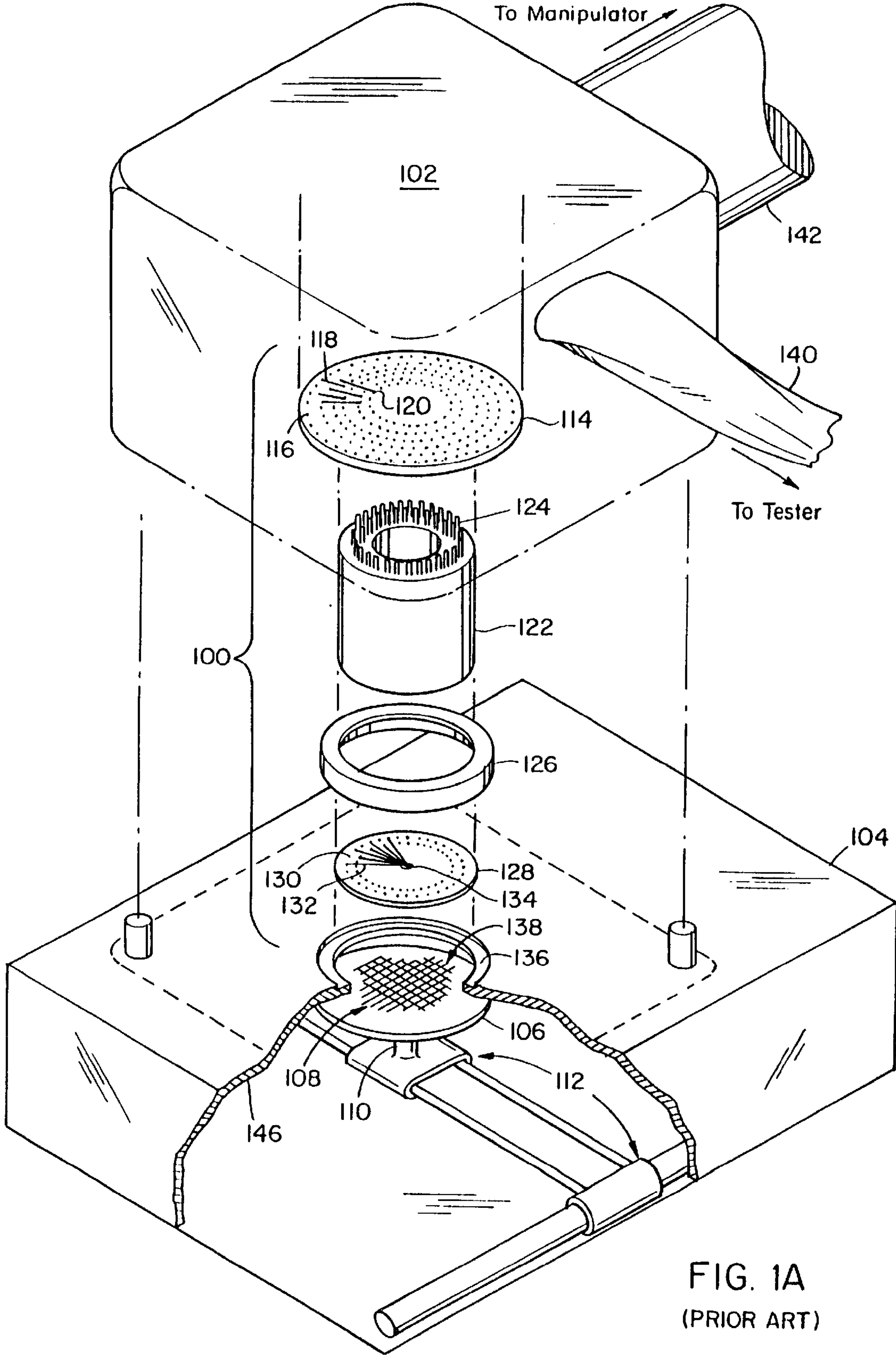


FIG. 1A
(PRIOR ART)

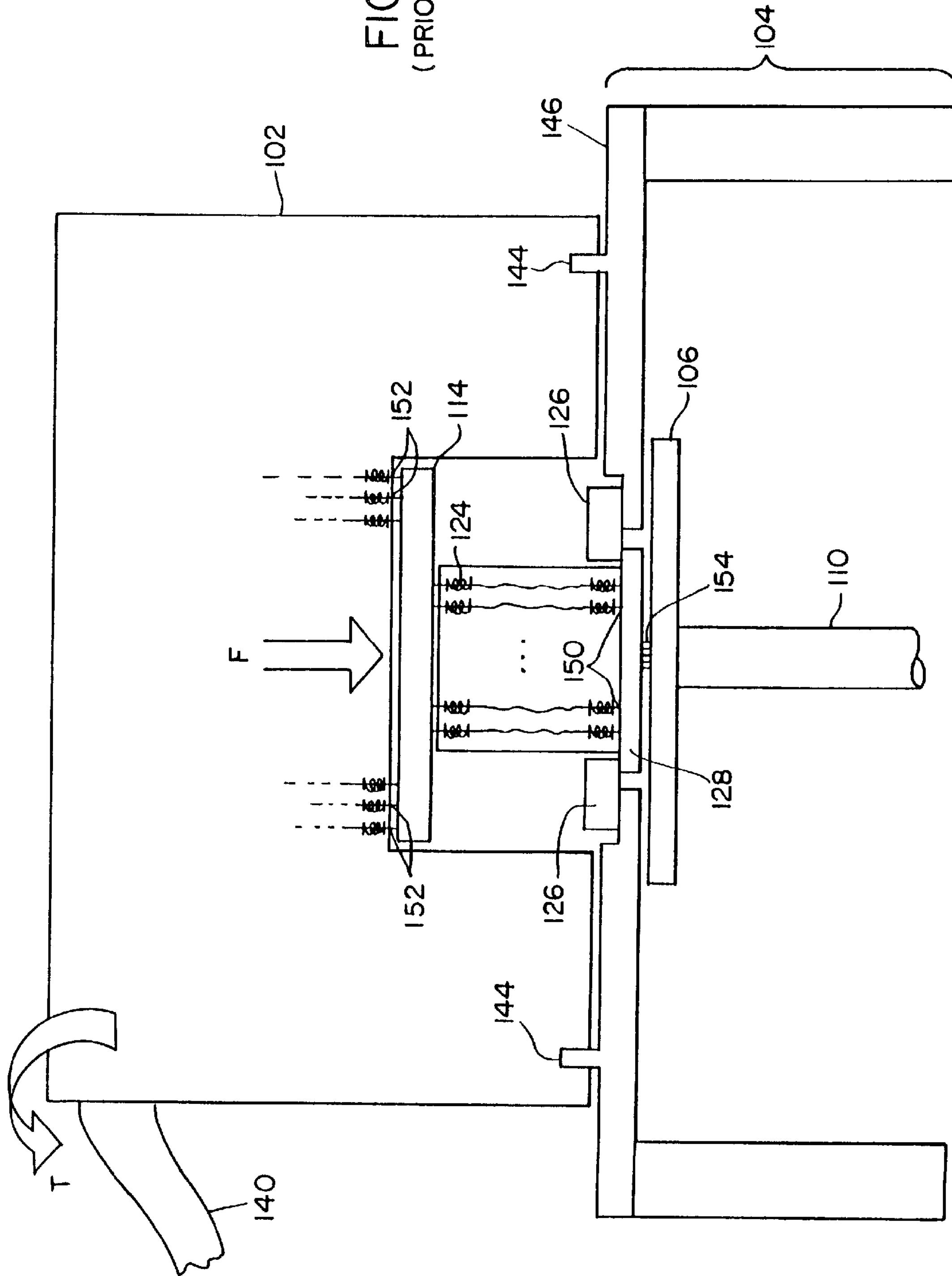


FIG. 1B
(PRIOR ART)
102
104
146
144
106
152
114
126
124
154
110
F
150
128
152
126
144
T
140

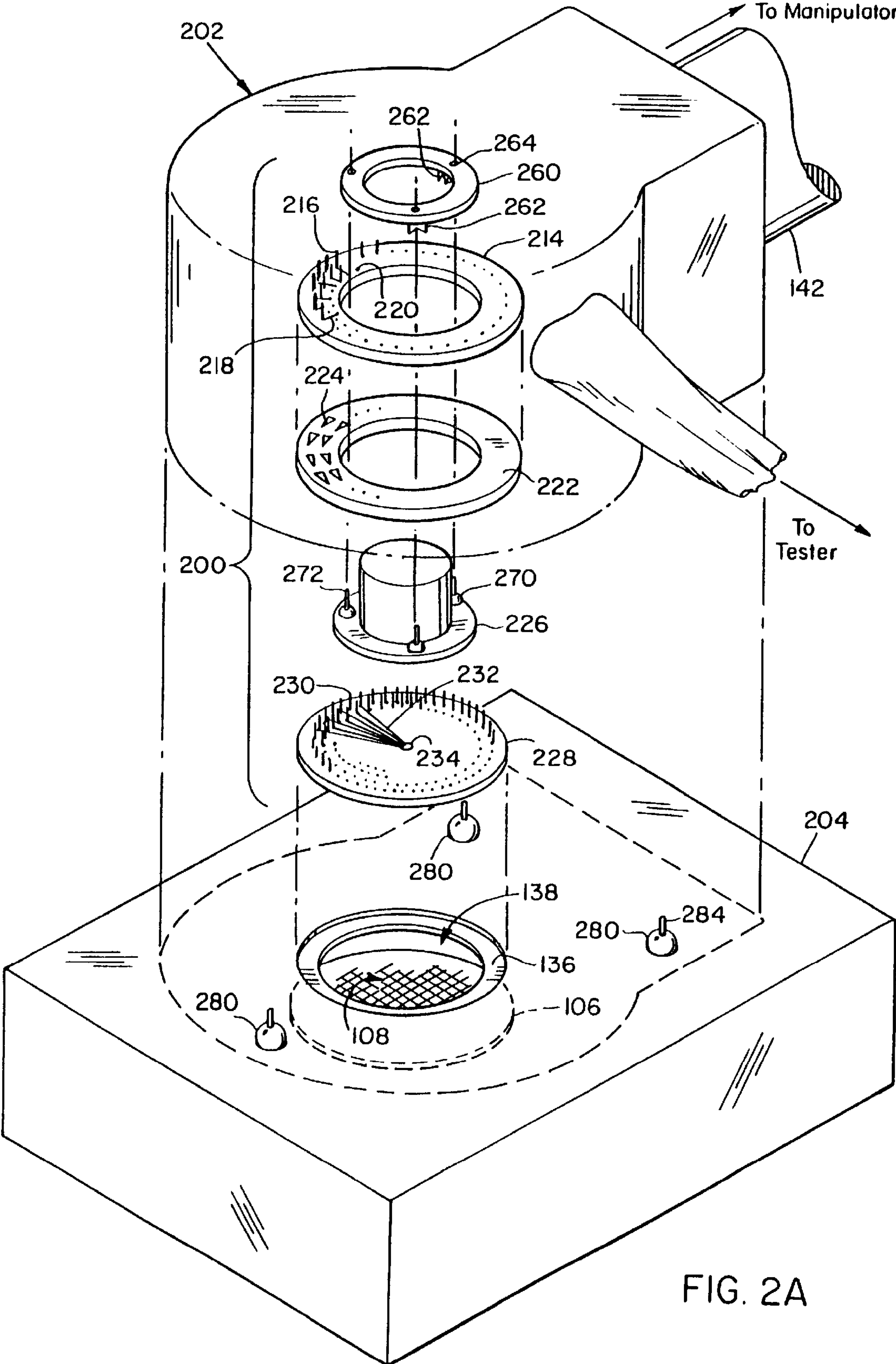


FIG. 2A

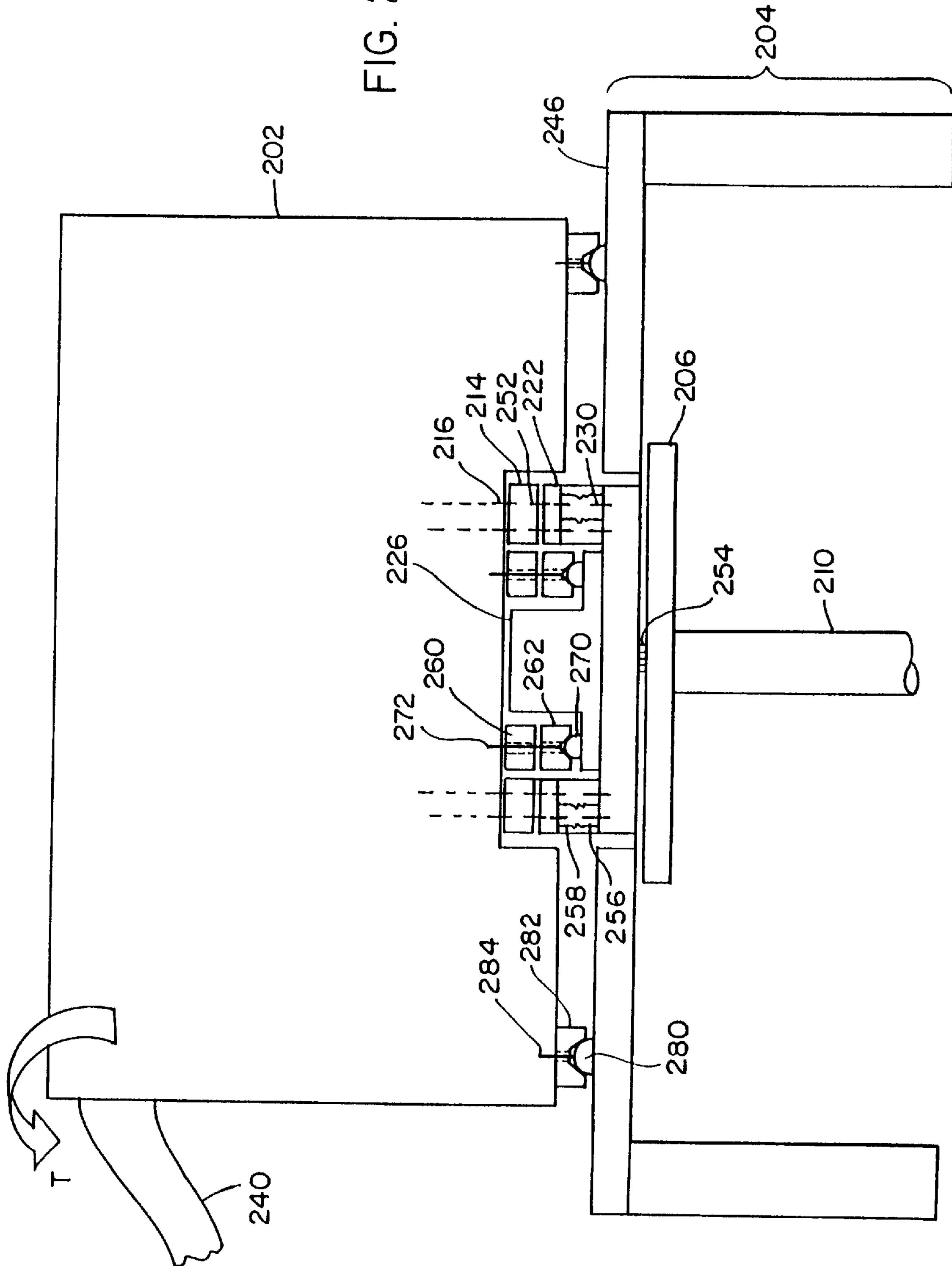


FIG. 2B
202
204
246
206
210
254
216
214
252
222
230
226
260
262
270
272
258
256
282
284
280
240
T

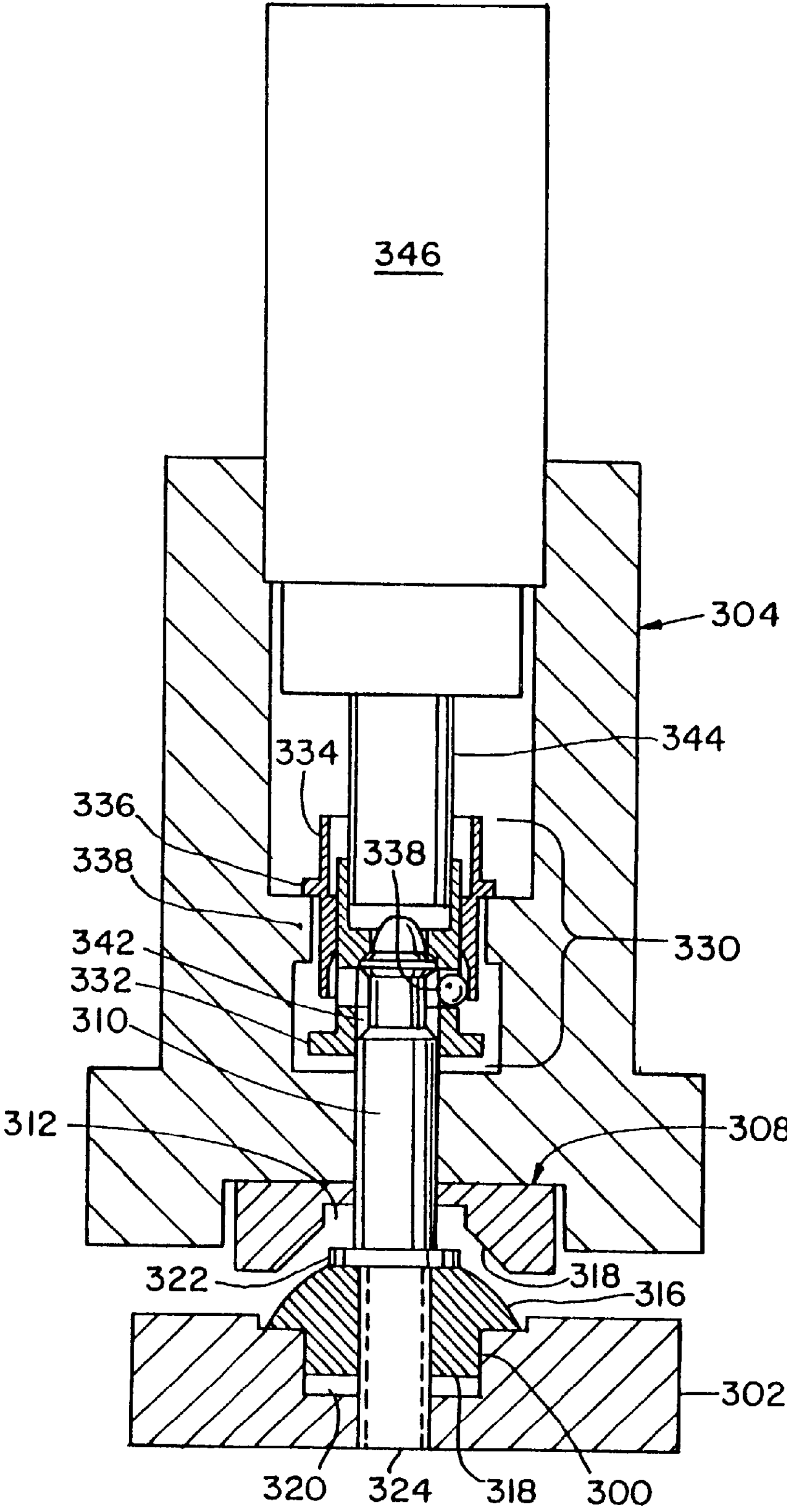


FIG. 3

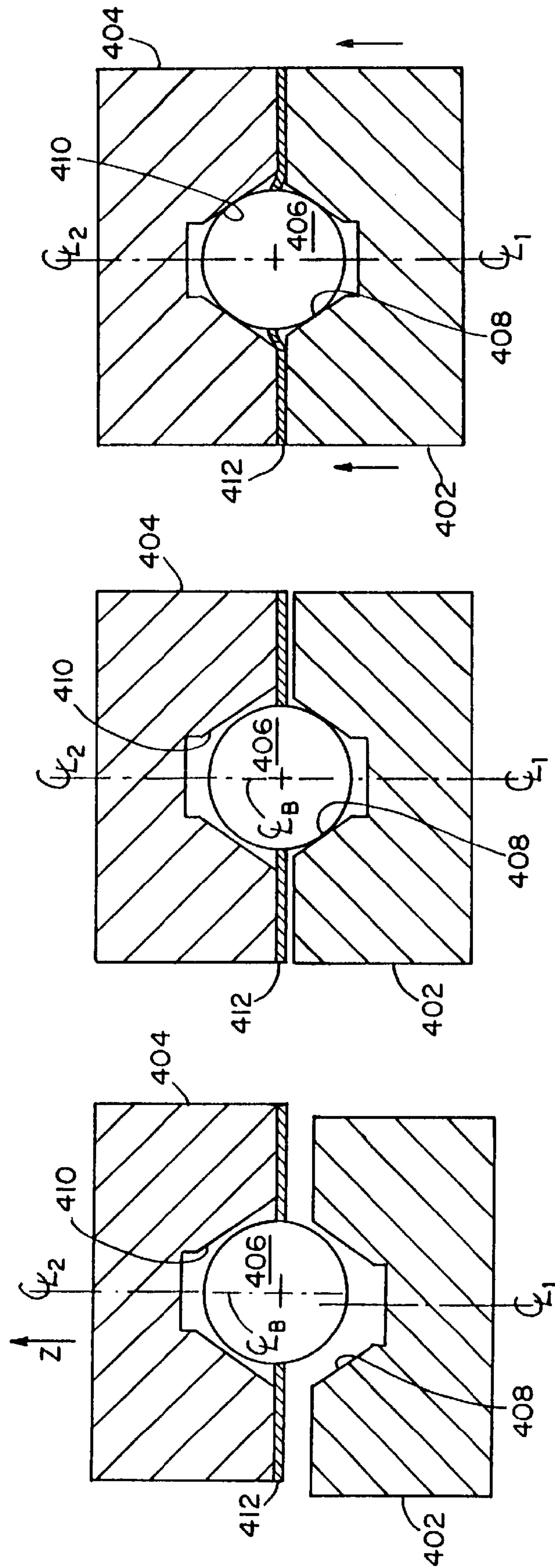


FIG. 4C

FIG. 4B

FIG. 4A

INTERFACE APPARATUS FOR AUTOMATIC TEST EQUIPMENT

This application is a continuation of application Ser. No. 08/754,581 filed on Nov. 21, 1996, now abandoned which is a divisional of application Ser. No. 08/463,227 filed on Jun. 5, 1995, now abandoned which is a divisional of application Ser. No. 08/299,831 filed on Sep. 1, 1994, now abandoned.

This invention relates generally to automatic test equipment and more specifically to apparatus for interfacing automatic test equipment to devices which position semiconductor devices for testing.

During the manufacture of semiconductor components, the components are tested at various stages. Manufacturers have significant economic incentive to detect and discard faulty components as early in the manufacturing process as possible. For example, numerous semiconductor integrated circuits are usually fabricated on a large silicon wafer. The wafer is cut and the integrated circuits are separated into dies. The dies are then mounted into frames. Bond wires are attached to connect the die to leads which extend from the frame. The frame is then encapsulated in plastic or other packaging material, producing a finished product.

This manufacturing process is relatively expensive. Accordingly, most semiconductor manufacturers test each integrated circuit on the wafer before the wafer is cut. The defective integrated circuits are marked and discarded after the wafer is cut. In this way, the cost of packaging the defective dies is saved. As a final check, most manufacturers test each finished product before it is shipped. Manufacturers who guarantee that a very high percentage of the semiconductor components delivered to their customers will function properly can charge higher prices for their products.

Semiconductor components are generally produced in large quantities. To rapidly test large quantities of components, automatic test equipment (generally "testers") are used. A tester rapidly generates input signals for application to the integrated circuit and can determine whether the appropriate response signals are generated. Because testers are highly automated, they can run through a series of millions of test cases in a few seconds.

To efficiently test integrated circuits, some device is needed to move and quickly connect the device being tested to the tester. To move wafers, a device called a "prober" is used. To move packaged parts, a device called an "handler" is used. These devices precisely position the component being tested so that it makes electrical contact with outputs of the tester. Probers, handlers and other devices for positioning a device under test relative to the test head are called generically "handling devices."

Connecting the handling device to the tester poses several challenges. First, semiconductor circuits have many inputs and outputs. Typical circuits might have between 20 and 100 inputs and outputs. However, some larger circuits have as many as 500 inputs and outputs and circuits with over 1,000 inputs and outputs are being contemplated. Thus, the tester must generate and receive hundreds of signals. The electronic circuitry needed for driving and receiving these signals must be as close to the device being tested as possible to allow high speed operation.

Consequently, most testers are designed with a test head that includes all of the driving and receiving circuitry. The test head is connected via a cable bundle to an electronics cabinet which contains data processing circuitry which determines which signals should be driven and compares the received signals to expected values.

The test head can be up to a few feet in diameter in order to hold all of the driving and receiving circuitry. The device being tested is on the order of a square inch in the case of a finished product and is even smaller in the case of an integrated circuit on a wafer. To make electrical contact, the hundreds of signals leaving the test head must be squeezed into a very small area.

FIG. 1A shows a test head **102** connected to a prober **104** through an interface **100**. Signals are connected to the electronics in test head **102** via spring pins **152** (FIG. 1B) Spring pins are conducting pins which are spring loaded so that when a conducting surface is pressed against the pins, a good electrical contact is made.

A device interface board **114** is pressed against the spring pins **152** (FIG. 1B) in test head **102**. Device interface board **114** is a multilevel printed circuit board. It includes on its upper level contact pads **116**. One of the spring pins **152** (FIG. 1B) presses against each contact pad **116** to route signals from test head **102** onto device interface board **114**. Device interface board **114** might also contain electronic components (not shown) needed to electrically interface the circuitry inside test head **102** to a specific device being tested.

On device interface board **114**, conductive traces **118** route the signals towards via holes **120** at the center of the board. Via holes **120** provide a conducting signal path to the bottom of device interface board **114**. Further contact pads (not shown) are positioned on the bottom of device interface board **114**.

Spring pins **124** in an extension collar **122** make contact to the contact pads (not shown) on the bottom of device interface board **114**. Extension collar **122** also includes spring pins **150** (FIG. 1B) on its lower surface. The spring pins **124** and **150** (FIG. 1B) are electrically connected inside extension collar **122** so that the electrical signals are passed through extension collar **122**.

Spring pins **150** (FIG. 1B) press against contact pads **130** on probe card **128**. Probe card **128** is also a multilevel printed circuit board. Contact pads **130** are connected to conductive traces **132** which route signals to via holes **134**. Via holes **134** carry the signals to the bottom of the probe card **128**. Via holes **134** are connected to probe wires **154** (FIG. 1B).

Probe card **128** is mounted in probe card stiffener **126**. Probe card stiffener **126** mechanically reinforces probe card **128**. Probe wires **154** (FIG. 1B) are precision manufactured such that their ends are all in e same plane. Deflection of probe care **128** would decrease this precision. Probe card stiffener **126** reduces deflection.

Probe card stiffener **126** rides on ledge **136** in upper surface **146** of prober **104**. Probe card stiffener **126** is fixedly attached to upper surface **146** so that probe wires **154** (FIG. 1B) are in a fixed position relative to prober **104**.

Inside prober **104**, a chuck **110** holds a silicon wafer **106**. Silicon wafer **106** has fabricated on its upper surface numerous integrated circuits **108**.

Chuck **110** is attached to X-Y positioning system **112**. Wafer **106** can be moved such that each of the integrated circuits **108** can be contacted in turn with probe wires **154** (FIG. 1B). Prober **104** can position wafer **106** with great precision. In addition, probers typically perform a calibration routine which allows the prober to determine the location of probe wires **154** such that prober **104** also operates with great accuracy as long as no portions of interface **100** move after the calibration routine is run.

One difficulty with such an arrangement, though, is that it is often necessary to change the device interface board **114** or probe card **128**. A different device interface board or probe card is likely to be needed to test different types of

components or to conduct different tests on the same type of component. To make the change, it is necessary that test head **102** be removed from prober **104**.

Test head **102** is a large device and can weigh in excess of 500 pounds. To facilitate movement, test head **102** is attached to a manipulator (not shown) via support arm **142**. The manipulator contains counterweights or other mechanical devices to make movement of test head **102** easier. The manipulator might also be calibrated such that when test head **102** is moved, it can be returned as closely as possible to the same location given its design and the tolerances in manufacture. Guide posts **144** on prober **104** also aid in returning test head **102** to its original position.

If, when test head **102** is repositioned, it is not in exactly the same place, the forces exerted on prober card **128** and upper surface **146** will be different than before the test head was moved. If the forces are sufficiently different, probe card **128** or upper surface **146** will deflect enough that probe wires **154** will move relative to wafer **106**. Sources of force are shown in FIG. 1B. Test head **102** must press against interface **100** (FIG. 1A) with sufficient force that spring pins **124**, **150** and **152** make good electrical contact. Locking rings (not shown) or other mechanical arrangements have been used to compress some of the spring pins. For example, a locking ring could be used to pull all the pieces of interface **100** together. However, one set of spring pins must always be compressed by a force F which pushes down on upper surface **146**.

Another source of force comes from cable **140**. Cable **140** is very heavy and may weigh hundreds of pounds. Cable **140** is very inflexible as it could be as large as twelve inches in diameter. It hangs off of test head **102** and applies a torque T. Because of the inflexible nature of the cable, it exhibits what is called an "hysteresis effect." Even if cable **140** is returned to exactly the same position, the torque applied to test head **102** might change after cable **140** is moved.

Any changes in these force can cause small deflections in probe card **128** or upper surface **146**. Movement of less than one thousandth of an inch is sufficient to require recalibration of prober **104**. As recalibration typically takes around twenty minutes, it would be highly desirable if test head **102** could be moved and repositioned such that it returned to the same location and exerts the same amount of force on probe card **128** and upper surface **146**.

Further, a calibration routine can only adjust for a displacement of test head **102** into a plane which is parallel to the upper surface of wafer **106**. This plane is sometimes called the X-Y plane. If test head **102** is tilted relative to the X-Y plane, some of the probe wires **154** might not contact wafer **106**. Likewise, if probe card **128** is distorted by force F or torque T such that the tips of probe wires **154** are no longer coplanar, some of the probe wires **154** will not contact wafer **106** in the appropriate places. Existing calibration routines can not compensate for these error sources. Accordingly, to achieve greater accuracy, it is necessary that any interface hold probe card **128** as flat and as parallel as possible to wafer **106**.

We have identified a second problem associated with moving test head **102**. Contact pads or spring pins are sometimes damaged as test head **102** is repositioned. If test head **102** is first moved perpendicularly to upper surface **146** such that the spring pins are pressed against their contact pads and then moved parallel with upper surface **146**, the spring pins will drag across the contact pads. If there is sufficient loading on the spring pins, the contact pads or spring pins will be damaged. Accordingly, it is desirable that the positioning system only allow motion of the test head perpendicular to upper surface **146** as test head **102** gets close to its final position.

SUMMARY OF THE INVENTION

With the foregoing background in mind, it is an object of the invention to provide an improved interface for automatic test equipment.

It is also an object to provide a mechanical interface between a test head and a handling device which precisely and repeatedly positions an electrical interface relative to the handling device.

It is another object to provide a mechanical interface between a test head and a handling device which provides constant force between the test head and the handling device.

It is still a further object to provide a mechanical interface between two bodies which allows only perpendicular motion

The foregoing and other objects are achieved by an interface involving kinematic coupling between the test head and the handling device. In one embodiment, the kinematic coupling is provided by curved components which mate with grooves. In a preferred embodiment, the curved components have posts extending therefrom which extend through holes in the grooves and are pulled with a constant force.

In another embodiment, a second kinematic coupling is used to mount a holder for the probe card to the test head.

In yet another embodiment, electrical contact is made between elements of the interface via zero insertion force sockets.

According to another feature of the invention, a mechanical coupling between two objects is formed from a kinematic surface mounted on each object with a body having two kinematic mating surfaces disposed between the kinematic surfaces. One mating surface faces each kinematic surface. The body is constrained to move in only one direction relative to one of the mating surfaces.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention may be better understood by reference to the following more detailed description and accompanying drawings in which:

FIG. **1A** is an exploded view of a prior art interface between a test head and a prober;

FIG. **1B** is a cross sectional view of FIG. **1A**;

FIG. **2A** is an exploded view of an interface according to the invention between a test head and a prober;

FIG. **2B** is a cross sectional view of FIG. **2A**;

FIG. **3** is a cross sectional view of a coupling according to one embodiment of the invention; and

FIGS. **4A** through **4C** are cross sectional views of a coupling according to an alternative embodiment of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

STRUCTURE

Turning now to FIG. **2A**, a test head **202** is shown interfacing with a handling device, such as prober **204**. Interface **200** includes a device interface board **214**, as in the prior art. However, unlike the prior art, device interface board **214** contains a plurality of electrically conductive posts **216**. Signals from test head **204** are passed onto device interface board **214** through posts **216**.

Posts **216** are connected to traces **218**. Traces **218** carry signals to via holes **220**. Via holes **220** carry the signals to the lower surface (not shown) of device interface board **214** and connect to posts **252** (FIG. 2B).

Zero insertion force ring **220** is mounted below device interface board **214**. Zero insertion force ring **220** contains holes **224** which receive posts **252**. Within the holes **224**, there are conductive plates **258** (FIG. 2B). Plates **258** are positioned such that posts **252** do not contact them when zero insertion force ring **220** is rotated into a first position. In this way, there is virtually no resistance to the insertion of posts **252** into holes **224**. However, plates **258** are arranged such that when zero insertion force ring **222** is rotated, posts **252** make electrical contact with plates **258**.

Probe card **228** is also included in interface **200**. Probe card **228** contains posts **230**. Posts **230** are align with holes (not shown) on the underside of zero insertion force ring **220**. Zero insertion force ring **220** contains plates **256** (FIG. 2B) which are positioned to electrically contact posts **230** when zero insertion force ring **220** is rotated.

As shown in FIG. 2B, plates **256** and **258** are connected together. Thus, when zero insertion force ring **220** is rotated, electrical paths are created for signals from device interface board **214** to probe card **228**. Though only a limited number of such conducting signal paths are shown, a typical tester will generate hundreds to over one thousand signals and a separate path is needed for each. Pins **216** on device interface card **214** could also be connected to test head **202** through a zero insertion force ring.

To complete the signal path, the signals are coupled over traces on probe card **228** to via holes **234**. The signals pass through via holes to the underside (not shown) of probe card **228**. Via holes **234** are connected to probe wires **254** (FIG. 2B) which contact wafer **206**.

Interface **200** provides electrical coupling from test head **202** to wafer **206**. Because spring pins are not used, no force perpendicular to upper surface **246** is required to establish the connection.

Probe card **228** is attached to probe card holder **226**. Any convenient means of attachment can be used. For example, probe card **228** could be screwed to holder **226**. Examples of other suitable methods of attachment are epoxy and snap fit coupling.

Probe card holder **226** includes three balls **270**. Posts **272** extend through the center of balls **270**. Balls **270** are designed to contact grooved blocks **262** mounted to positioning ring **260**. Balls **270** and grooved blocks **262** are machined from a rigid, hard material. Hardened stainless steel is one example of a suitable material. Silicon carbide or silicon nitride could also be used, but are more difficult to machine. Grooved blocks **262** and balls **270** mate to form a kinematic coupling which precisely and repeatably positions probe card **228** relative to test head **202**. Kinematic coupling is described in greater detail below.

Positioning ring **260** is mounted to test head **202** in a manner described in greater detail below. Posts **272** are designed to pass through holes **264** in positioning ring **260**. Holes **264** should be sufficiently large that posts **272** do not touch the sides of holes **264**. Posts **272** engage a linear actuator **346** (FIG. **3**), which holds probe card holder **226** to test head **202** with a constant force. That force is constant regardless of the position of test head **202**.

Test head **202** has mounted on its lower surface three grooved blocks **282** (FIG. 2B). Grooved blocks **282** receive balls **280** mounted on upper surface **246** of prober **204**. Grooved blocks **282** and balls **280** are machined from a rigid, abrasion resistant material, such as stainless steel.

Pins **284** pass through holes in grooved blocks **282** and engage a linear actuator **346** (FIG. **3**) in test head **202**. Linear actuator **346** holds test head **202** to prober **204** with a constant force.

ASSEMBLY

Grooved blocks **262** and **282** are made separately. Likewise, balls **270** and **280** are made separately. These pieces are preferably machined to tight tolerances (+/−0.0001" with a surface roughness of 0.00001" or better. Posts **272** and **284** need not be manufactured with the same tight tolerances. They are manufactured separately and then attached to balls **270** and **280**. One suitable means of attachment is be threading the ends of posts **272** and **284** and then screwing them into a threaded hole in balls **270** and **280**.

Grooved blocks **282** are affixed to the lower surface of test head **202** in any convenient, rigid manner. For example, screws can be used. For greater stability, grooved blocks **282** are mounted as close to the periphery of test head **202** as possible. As a kinematic coupling will form a stable and repeatable attachment regardless of the exact position of the contacts, the positioning of grooved blocks **282** is not critical. For ease of assembly, it is preferable if the kinematic couplings are attached to the lower surface of test head **202** while it is detached from the rest of the test head.

Next, positioning ring **260** is produced. As it is much smaller than the entire test head, grooved blocks **262** could be formed as part of ring **260** or could be separately formed and then attached, such as with screws, to ring **260**. To ensure that probe card holder **226** and hence probe card **228** are parallel to upper surface **246**, it is necessary that grooved blocks **262** be mounted parallel to grooved blocks **282**. To ensure proper positioning, a precision manufactured jig is used. The jig is made on a very stable, flat surface as is customarily used in the manufacture of precision equipment. Three posts with spherical ends are mounted on the surface to mate with the grooves in grooved blocks **282**. The heights of the posts of the jig are carefully controlled to be the same such that the lower surface of test head **202** is parallel with the flat surface of the jig. Another set of three balled posts is mounted on the flat surface of the jig. The heights of these posts are also carefully controlled to be the same height such that when positioning ring **260** is placed on the posts it will be precisely parallel to the flat surface of the jig and hence parallel to the lower surface of test head **202**.

Positioning ring **260** is manufactured to be slightly smaller than the opening in test head **202** into which it fits. A clearance of 0.3" is used in the preferred embodiment, but the exact dimension is not critical. To hold positioning ring **260** in the right location, positioning ring is potted in epoxy or other suitable replicant. Epoxy of the type used as a replicant in the machine tool industry is suitable.

Probe card holder **226** is separately manufactured. Because probe card holder **226** is relatively small, it is possible to position balls **270** using traditional high precision manufacturing techniques without the use of a separate jig. Also, balls **270** do not need to be positioined with high accuracy because the probe wires on probe card **228** are planarized, using known techniques, while probe card **228** is mounted in probe card holder **226**. Thus, any skew of probe card holder **226** relative to upper surface **246** introduced by inexact placement of balls **270** in the planarization process.

Prober **204** may be manufactured separately and balls **280** may be mounted after prober **204** is manufactured. Again, the exact plane above upper surface **246** where balls **280** mate with grooved blocks **282** is not critical. Accordingly, special procedures do not need to be employed to mount

balls **280**. As shown in greater detail in conjunction with FIG. **3**, balls **280** are not fully spherical. Rather, posts are machined at one end to have one spherical end. The other end of the post could then be threaded for attachment to prober **204**. Other methods of attachment could be used. For example, screws could be inserted through upper surface **246** to hold balls **280**.

Prober **204** can easily compensate for displacements of probe card **228** in the plane of upper surface **246** (the X-Y plane). Prober **204** can not, however, compensate for the fact that probe card **228** is not parallel to upper surface **246**. Therefore, the heights of balls **280** above upper surface is important to achieve the accuracy desired for the preferred embodiment.

One way to achieve this accuracy is to make the relative heights of balls **280** adjustable. Commercially available probers generally have an upper surface which may be adjusted. If balls **280** are mounted to upper surface **246**, proper positioning can be attained by simply adjusting upper surface **246**. The adjustment may be made with the aid of a precision manufactured adjustment jig.

A suitable jig would have **3** grooves positioned on a flat plate like the grooves in grooved blocks **282** mounted to the underside of test head **202**. In the center of the jig, three displacement transducers would be mounted with their tips located in a plane parallel with the flat plate of the jig. The tips of the displacement transducers would point downwards towards a test surface mounted in chuck **210**. Upper surface **246** would then be adjusted until all three displacement transducers had the same reading. Such a condition indicates that the tops of balls **280** define a plane parallel to the piece on chuck **210**.

Alternatively, it is not necessary that a separate jig be constructed to adjust the heights of balls **280**. If probe card **228** were replaced by a fixture holding three displacement transducers, it would function exactly as the jig described above.

Also, it is not necessary that a prober having an adjustable upper surface be used. It might be preferable to mount balls **208** to the frame of prober **204** as the frame is less likely to move than the upper surface and allows the balls to be more widely spaced for greater stability. If balls **208** are mounted directly to the frame or are mounted to a prober without an adjustable upper surface, it is preferable that they be mounted with some means that allows adjustment of their height. For example, they could be mounted with micrometer head screws.

OPERATION OF KINENATIC COUPLING

Kinematic coupling is well known. It is described in reference texts such as *Precision Machine Design* by Alexander H. Slocum, Prentice Hall 1992 and in papers such as A. Slocum, *Kinematic Coupling For Precision Fixturing—Part 1: Formulation of Design Parameters*, Precis. Eng., Vol. 10 No. 2, 1988; A. Slocum and A. Donmez, *Kinematic Couplings for Precision Fixturing—Part 2: Experimental Determination of Repeatability and Stiffness*, Precis. Eng., Vol. 10, No. 3, 1988; and *Design of Three-Groove Kinematic Couplings* by Alexander H. Slocum, Precis. Eng., pp 67–75, 1992, all of which are hereby incorporated by reference. Briefly, the theory behind kinematic coupling is that to accurately position a body, it should be contacted at the fewest number of points needed to constrain motion in all degrees of freedom in which motion is to be prohibited. To constrain motion in the six degrees of freedom, six contact points are needed, provided that no more than two of the contact points are colinear.

In the preferred embodiment, three balls are mated in three grooves. Each groove has two surfaces, each of which contacts a ball at only one point. Thus, the combination of three balls and three groves forms a kinematic coupling sufficient to restrain motion in the six degrees of freedom.

In the preferred embodiment, the grooves are as widely spaced as practical. In addition, the grooves are oriented to provide the greatest possible stability according to the techniques detailed in the aforesaid references.

Each pair of a ball and groove is termed a "kinematic contact" because the pair provides some of the contacts needed to form the kinematic coupling. Each side of a groove is termed a "kinematic surface" because it provides for contact at a single point. The ball is called a "kinematic mating surface" because it contacts a kinematic surface at only one point. For satisfactory operation of a kinematic coupling, it is not necessary that grooves be used to form the kinematic surfaces. Other shapes, such as a gothic arch, can be used as well. It is also not necessary that a ball be used as the kinematic mating surface. Other shapes, such as the tip of a cone, can be made to contact a surface at a single point. Likewise, it is not necessary that each kinematic contact include two kinematic surfaces. Examples of other suitable kinematic contacts are: a ball pressing against a flat surface (one kinematic surface per contact); a ball pressing against a tetrahedron (three kinematic surfaces per contact) or a ball pressing against three balls (three kinematic surfaces per contact). Different types of contacts may be used in one coupling as long as there are six kinematic surfaces in total.

Turning now to FIG. **3**, greater detail is shown of the kinematic contact of the preferred embodiment. FIG. **3** shows body **302** coupled to body **304**. Ball portion **306** is mounted to body **302**.

Ball portion **306** has a curved portion **316** adapted to contact tapered surface **314** in grooved block **308**. Ball portion **306** need not be fully spherical. Regions of ball portion **306** which do not contact grooved block **308** may be any shape to facilitate manufacture. Here, plug portion **318** is adapted to fit into recess **320** to hold ball portion **306** in place.

Post **310** extends through ball portion **306**. Post **310** has a threaded end **324** which is screwed to body **302**. Flange **322** on post **310** aids in holding ball portion **306** to body **302**.

Grooved block **308** contains a recess **312**. Recess **312** is large enough that when curved portion **316** engages tapered surface **314**, post **310** and flange **322** do not contact grooved block **308**.

Grooved block **308** is mounted to body **304**. Post **310** extends into body **304** and mates with quick connect coupling **330**. Coupling **330** is any coupling which can grab post **310**, pull on it and release it. Couplings performing these motions with the fewest motions possible are preferred.

One coupling suitable for use as quick connect coupling **330** is a quick connect coupling as is sometimes used to connect an air hose to a compressor. It has an inner sleeve **332** and an outer sleeve **334**. Outer sleeve **334** slides relative to inner sleeve **332**. Outer sleeve **334** is connected to inner sleeve **332** by a spring which urges outer sleeve **334** downwards.

Quick connect coupling **330** also includes ball **340**. Usually, three or four such balls are included, but only one is shown for clarity. FIG. **3** shows ball **340** engaged in recess **342** of post **310** with outer sleeve **334** holding ball **340** in place.

Inner sleeve **332** is connected to plunger **344**. Plunger **344** is in turn connected to linear actuator **346**. Linear actuator may be any device which can depress plunger **344** towards post **310** and to pull back on plunger **344** with a constant force. Here, a pneumatic cylinder is used.

In operation, post **310** is inserted into body **304**. Post **310** presses against ball **340**. Ball **340** causes outer sleeve **334** to ride up relative to inner sleeve **332**. When outer sleeve rides up far enough to clear ball **340**, ball **340** slides away from post **310**. Post **310** can then move past ball **340** and ball **340** can slide into recess **342**. The spring loaded force on outer sleeve **334** then pulls outer sleeve **334** back down, forcing ball **340** into recess **342**. Outer sleeve **334** slides down sufficiently far to prevent ball **340** from coming out of recess **342**, thereby locking post **310** in place.

With ball **340** engaged in recess **342**, actuator **346** then pulls upwards on plunger **344** with a predetermined amount of force. As plunger **344** is connected to quick connect coupling **330** which is in turn connected to post **310**, this upward force pulls ball portion **306** against grooved block **308**. Thus, the contact force at the kinematic contact is the force provided by linear actuator **346**. To have repeatable positioning, it is important that the contact force at each kinematic contact be repeatable.

Actuator **346** and quick connect coupling **330** are preferably mounted such that the only force they exert on post **310** is along the axis of the post **310**. To achieve this result, actuator **346** could be mounted with a ball and socket mounting or on an elastomer. Also, there should be sufficient spacing around quick connect coupling to prevent it from contacting body **304**.

To release quick connect coupling **330**, plunger **344** is depressed further. Both outer sleeve **334** and inner sleeve **332** are pressed downwards further than needed to engage the coupling. Downward motion of outer sleeve **334** stops when flange **336** engages tab **338**. As plunger **344** is depressed further, ball **340** rolls below outer sleeve **334** and springs out of recess **342**. In this way, the connection is released.

Actuator **346** can be controlled by a control system (not shown) or could operate in response to a human operator pressing various switches. In operation, it is expected that a robotic manipulator (not shown) or even a human operator bring test head **202** close enough to prober **204** that posts **284** engage quick connect couplings inside test head **202**. Thereafter, the manipulator would exert as little force as possible on test head **202** such that all contact forces were supplied by the actuators. In this fashion, part-per-million repeatability can be obtained.

ALTERNATIVE EMBODIMENTS

FIG. **4**A shows an alternative embodiment of a kinematic contact. A body **402** is coupled to a body **404**. Body **402** has a groove **408** formed in it. Body **404** has a groove **410** formed in it.

Ball **406** is attached over groove **410** on flexural bearing **412**. A flexural bearing resembles a thin sheet of metal. Flexural bearing **412** allows ball **406** to move in the direction labeled Z. However, it does not allow motion in any direction perpendicular to the direction Z.

The center line CL_B of ball **406** is aligned with the center line CL_2 of groove **410**. In operation, bodies **402** and **404** are brought together. Ball **406** will first settle into groove **408** and align the center line CL_1 of groove **408** with the center line CL_B of ball **406**, as shown in FIG. **4**B. As bodies **402** and **404** are brought closer together, ball **406** will be pressed into groove **410**, as shown in FIG. **4**C. Once ball **406** engaged groove **408** as in FIG. **4**B, all further motion of bodies **404** and **402** is in the Z direction. No perpendicular motion is permitted.

FIGS. **4**A–**4**C does not explicitly show how the force is applied to to bring bodies **402** and **404** together. A post passing through ball **406** as shown in FIG. **3** might be used.

Other methods of allowing only one directional motion of ball **406** could be employed. For example, ball **406** could ride on a post extending from the floor of groove **410**. In that embodiment, ball **406** might be biased away from body **404** by a spring or some other mechanism.

The kinematic coupling of FIGS. **4**A–**4**C are particularly useful for interfaces using spring pins. With such a coupling, once the test head is close enough to the prober to put force on the spring pins, no lateral movement of the pins will be permitted. Damage to contact pads by the spring pins is thereby avoided.

Various changes and substitutions could also be made to the disclosed preferred embodiments without departing from the invention. For example, FIG. **3** shows a pneumatic actuator used to apply a preload force to a kinematic contact. Any other means of applying a preload force could be used.

Also, various manufacturing tolerances are listed throughout the description. A functioning device could be made even if these tolerances are not strictly observed, though it might have less accuracy than described. Likewise, a device could be made with greater tolerances and should have greater accuracy.

Balls and grooves are shown as the kinematic contacts. The position of the balls and grooves could be interchanged. For example, grooves **282** could be mounted on prober **204** and balls **280** could be mounted on test head **202**. Also, the kinematic contacts need not be limited to balls and grooves. Any kinematic contacts forming a kinematic coupling could be used.

Further, the disclosed embodiment shows an outer kinematic coupling test head **202** to prober **204** and an inner kinematic coupling probe card **228** to test head **202**. Benefits could be obtained by using only one of these couplings.

Also, FIGS. **2**A–**2**B show a zero insertion force ring used to implement a zero insertion force socket. Other types of zero insertion force sockets could be used. For example, some zero insertion force sockets are implemented by squeezing a post inserted into the socket between two conductive members. One conductive member is connected to a lever and moves towards the other when the lever is moved.

Further, a probe card with probe wires was illustrated. The invention can be used regardless of the method used to probe a device. For example, the invention works equally well if a conductive membrane or blades are used for probing a wafer.

Additionally, probe cards and device interface boards were illustrated as being printed circuit boards. Any substrate which carries conductive paths might be used.

It should also be noted that the invention was illustrated when used to interface a test head to a prober. The invention may also be used as an interface to a handler for packaged IC parts. If used with a handler, there might be no need for a probe card. Traditionally, handlers plug packaged parts into sockets mounted to the device interface board. Also, handlers generally are oriented vertically whereas probers generally are oriented horizontally. The interface of the invention is useful in all orientations.

It is felt, therefore, that the invention should be limited only by the spirit and scope of the appended claims.

What is claimed is:

1. Apparatus for automatically testing semiconductor components comprising a tester and a handling device with a coupling between the tester and the handling device, wherein:

the coupling comprises a plurality of contacts, each having at least a first part and a second part, the first part

being attached to one of the tester and the handling device and the second part being attached to the other of the tester and the handling device; and wherein at least one of the plurality of contacts comprises:

i) the first part comprising a grooved member, the grooved member having a first surface and a second surface bounding the groove;

ii) the second part comprising a rounded member having curved surface contacting the first surface and the second surface of the grooved member.

2. The automatic test equipment apparatus of claim **1** wherein the plurality of contacts collectively define six points of contact between the first parts and the second parts.

3. The automatic test equipment apparatus of claim **1** wherein the coupling comprises two additional grooved members.

4. The apparatus of claim **1** wherein the coupling comprises a preloaded coupling.

5. The apparatus of claim **4** wherein the preloaded coupling comprises:

a) a post extending from said curved surface of the second part; and

b) means for applying a force to the post.

6. The apparatus of claim **5** wherein the first part has a hole formed therethrough, said hole having a diameter larger than the diameter of the post, and the first part being disposed between the second part and the means for applying a force.

7. The apparatus of claim **1** additionally comprising:

a) a probe card holder;

b) a kinematic coupling between the probe card holder and the test head.

8. The apparatus of claim **7** additionally comprising:

a) a body;

b) replicant securing the body to the test head; and

c) wherein the kinematic coupling comprises a plurality of kinematic surfaces on the body and a plurality of kinematic mating surfaces on the probe card holder.

9. Automatic test equipment apparatus comprising:

a) a test head;

b) an handling device adapted to hold a device under rest in a first plane;

c) a probe card having a plurality of probe wires on a lower surface thereof;

d) a probe card holder, fixedly attached to the probe card;

e) a first coupling between the probe card holder and the test head;

f) a second coupling between the test head and the handling device;

g) wherein at least one of the first and second couplings comprises a contact having:

i) a first part comprising a grooved member, the grooved member having a first surface and a second surface bounding the groove;

ii) a second part comprising a rounded member having a curved surface contacting the first surface and the second surface of the grooved member.

10. The automatic test equipment apparatus of claim **9** wherein the first and second couplings comprise preloaded couplings.

11. The automatic test equipment apparatus of claim **10** wherein:

a) the grooved member has a hole therethrough;

b) the second part additionally comprises a post extending from the curved surface, said post extending through the hole; and

c) the automatic test equipment additionally comprises means for engaging the post and applying a preload force to the post.

12. The automatic test equipment apparatus of claim **10** wherein each of the kinematic couplings includes a kinematic surface, and additionally comprising a member having a flat surface, said member fixedly attached to the test head and said flat surface having mounted thereto the kinematic surfaces of the coupling between the probe card holder and the test head.

13. The automatic test equipment apparatus of claim **12** additionally comprising:

a) a device interface board having a first plurality of conductive posts extending therefrom;

b) a second plurality of conductive posts extending from the probe card; and

c) a zero insertion force socket connecting the posts on the device interface board to the posts on the probe card.

14. The automatic test equipment apparatus of claim **13** wherein the zero insertion force socket has an annular shape with a hole therethrough and the probe card holder has a portion extending through the hole.

15. An automated test system for use in testing semiconductor components comprising:

a) a first housing enclosing electronic circuitry for driving and receiving test signals, the first housing having a first surface;

b) a contact mechanism, connected to the first housing, and adapted to make electrical contact to a semiconductor component under test;

c) a second housing enclosing apparatus for holding semiconductor components under test, the second housing having a second surface; and

d) a coupling between the first surface and the second surface wherein the coupling comprises at least one contact having

i) a first part comprising a grooved member, the grooved member having a first surface and a second surface bounding the groove;

ii) a second part comprising a rounded member having a curved surface contacting the first surface and the second surface of the grooved member.

16. The automated test system of claim **15** wherein the first housing comprises a test head.

17. The automated test system of claim **15** wherein the coupling consists of three like contacts.

18. The automated test system of claim **15** wherein the coupling is formed from a plurality of first members, separate from the first surface, mounted to the first surface and a plurality of second members, separate from the second surface, mounted to the second surface.

19. The automated test system of claim **18** wherein the plurality of first members are blocks having grooves formed therein.

20. The automated test system of claim **15** wherein the coupling is a kinematic coupling which positions the first housing relative to the second housing in six degrees of freedom.

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