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(54) **APPARATUS AND METHOD FOR LIMITING OVER TRAVEL IN A PROBE CARD ASSEMBLY**

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(57) **ABSTRACT**

Methods and apparatuses for testing semiconductor devices are disclosed. Over travel stops limit over travel of a device to be tested with respect to probes of a probe card assembly. Feedback control techniques are employed to control relative movement of the device and the probe card assembly. A probe card assembly includes flexible base for absorbing excessive over travel of the device to be tested with respect to the probe card assembly.

5
10
16
16
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14
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SUPPORT STRUCTURE
22
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17
23
21
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12
18
11
28
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21
CONTROL APPARATUS
13

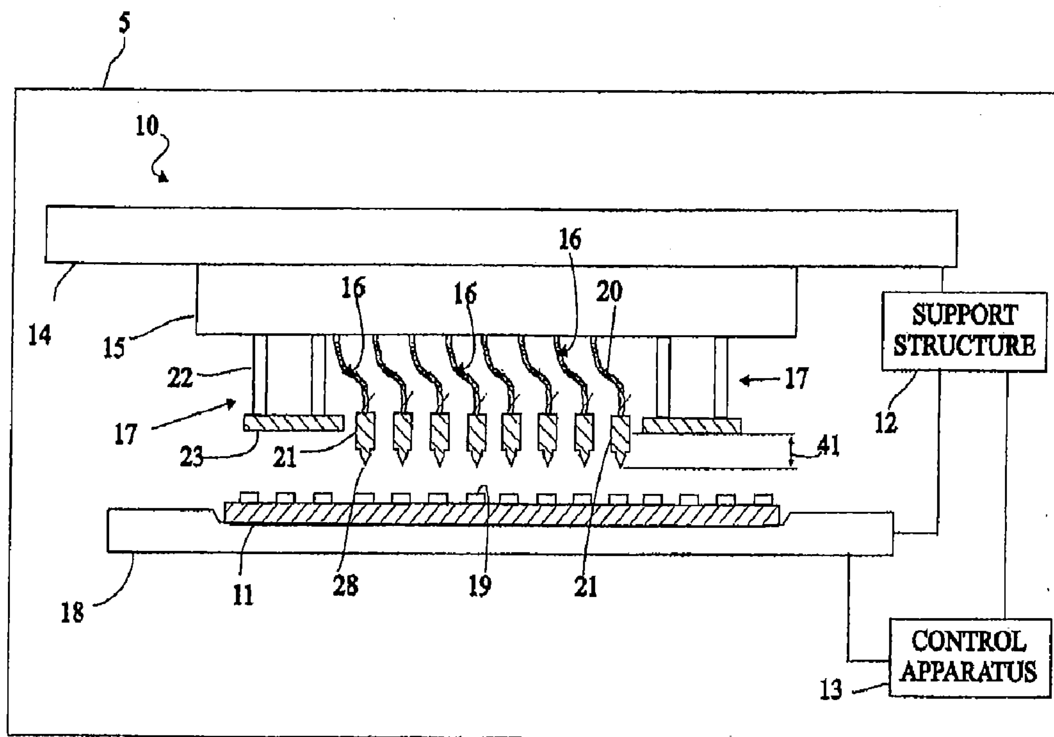

Fig. 1

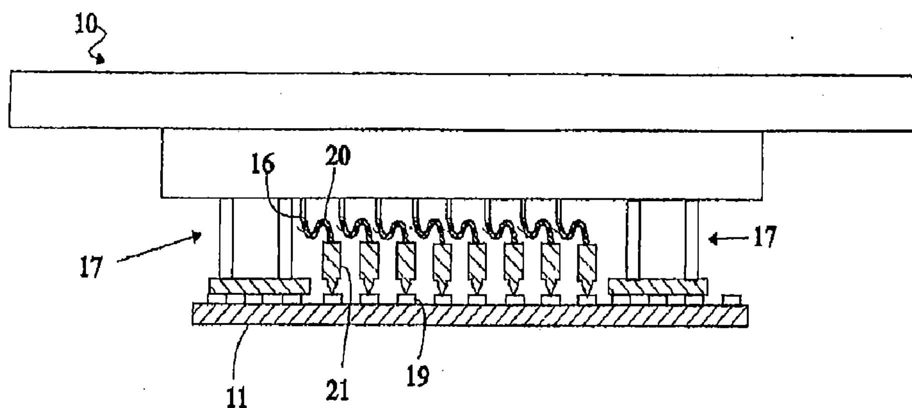

Fig. 2

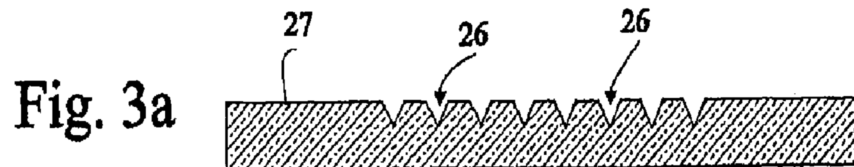

Fig. 3a

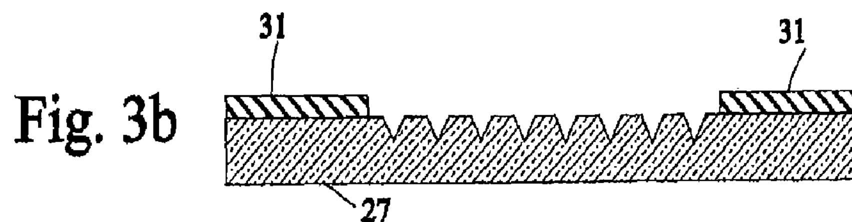

Fig. 3b

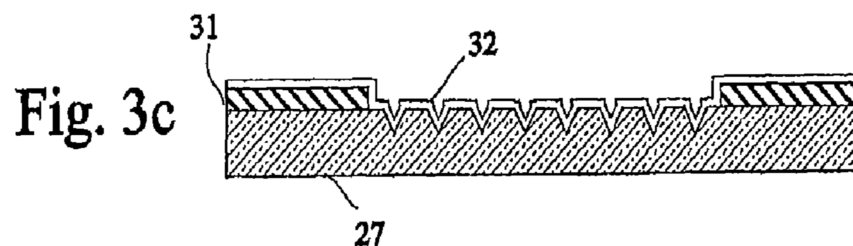

Fig. 3c

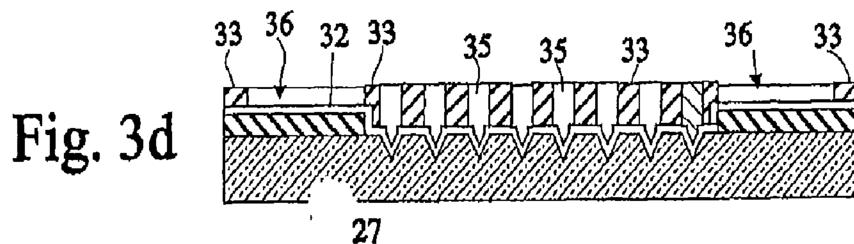

Fig. 3d

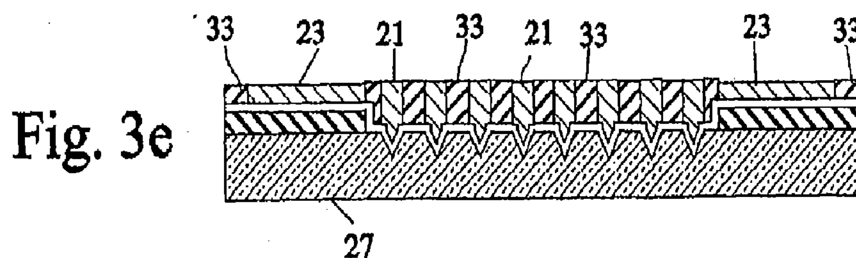

Fig. 3e

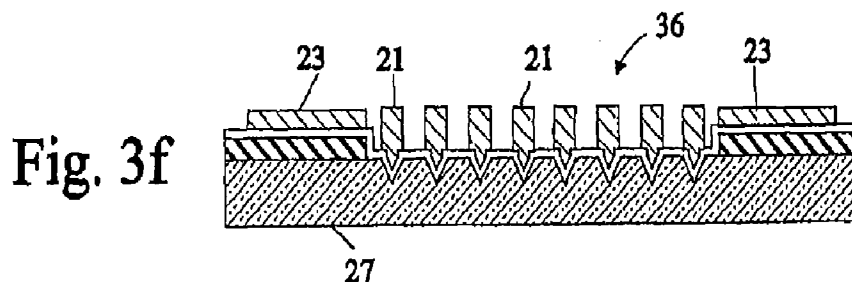

Fig. 3f

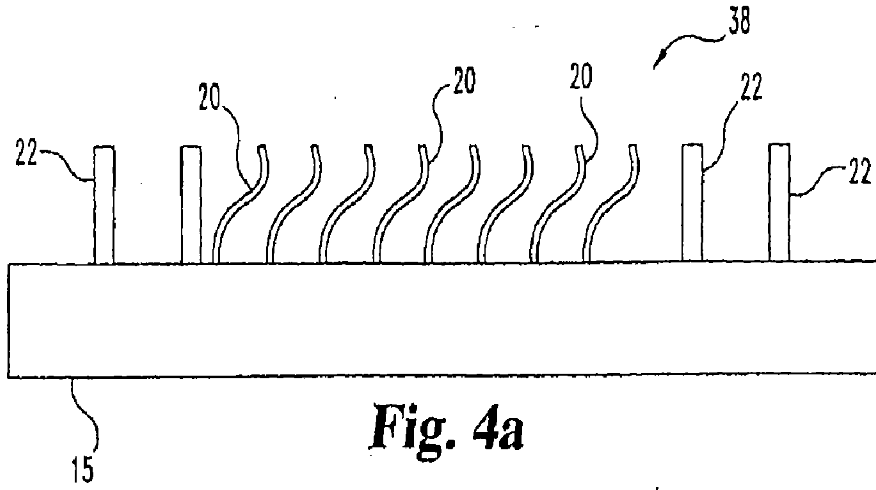

Fig. 4a

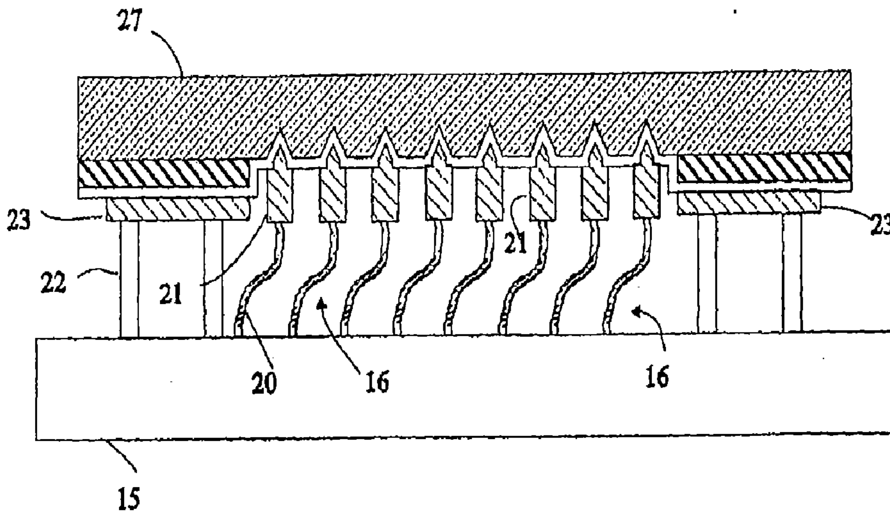

Fig. 4b

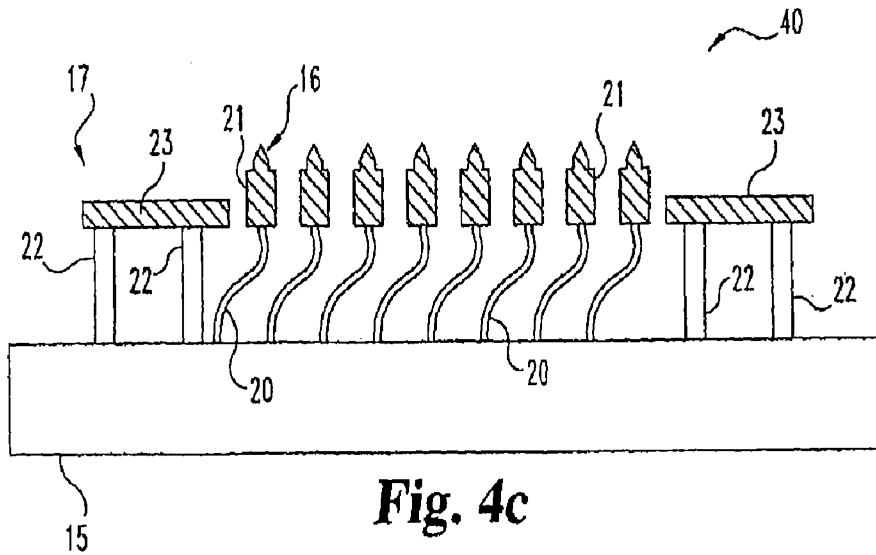

Fig. 4c

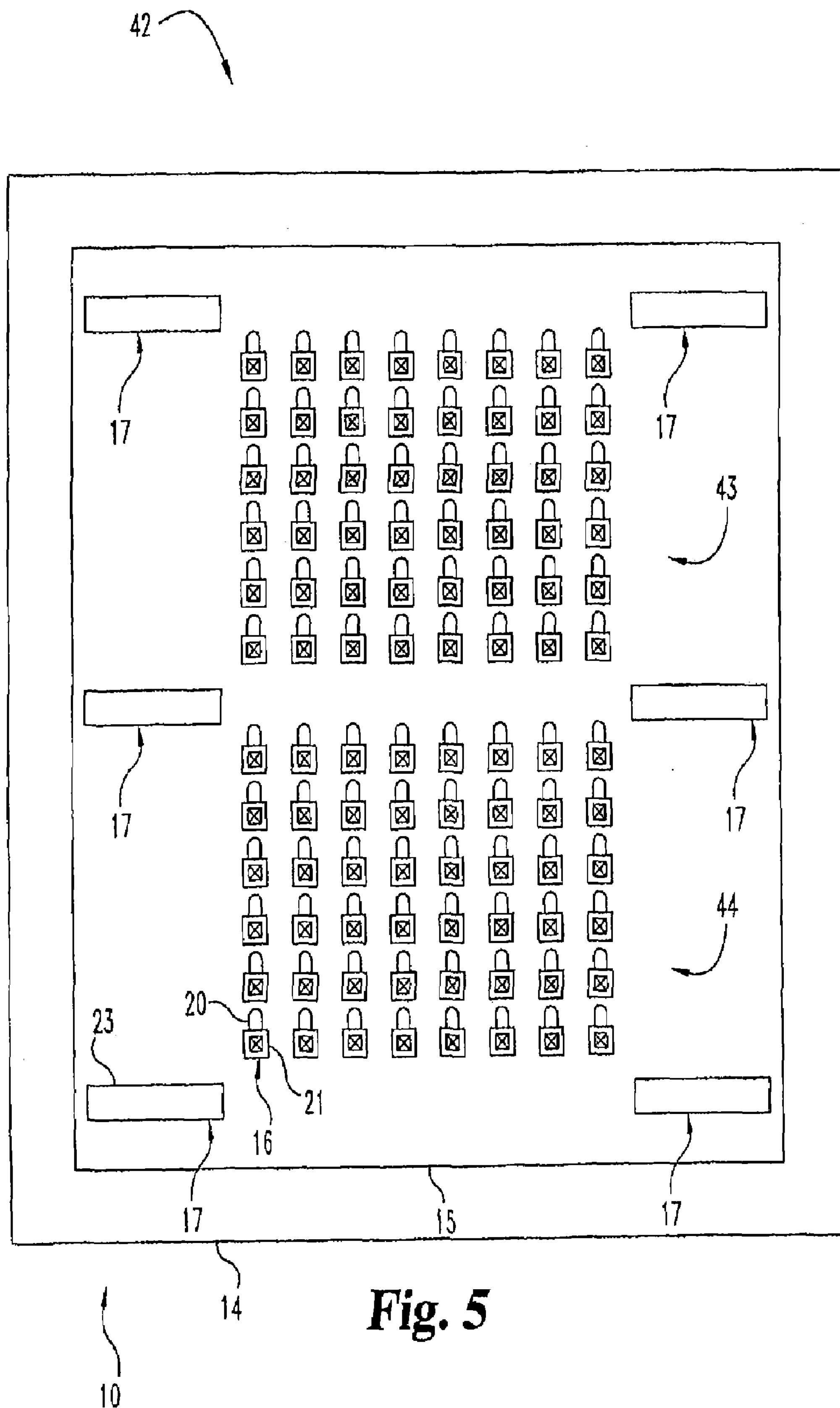

Fig. 5

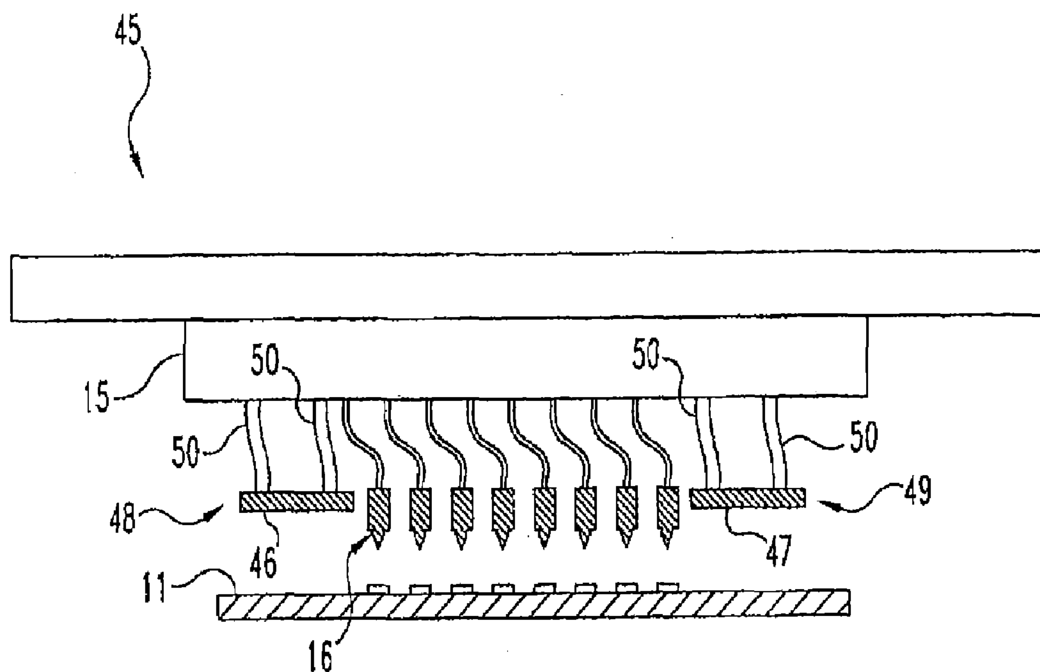

Fig. 6

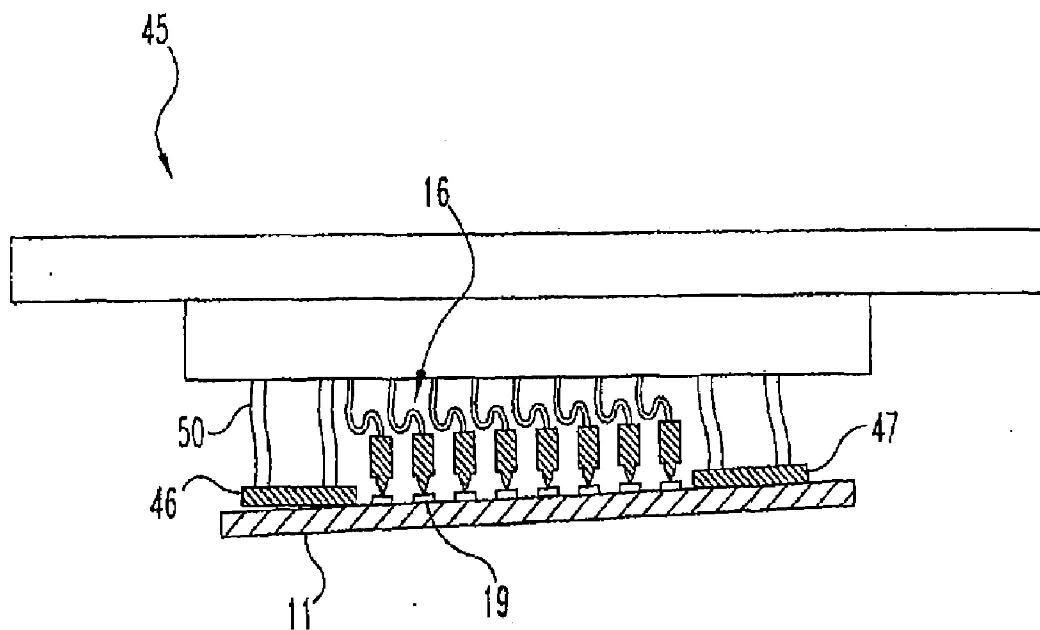

Fig. 7

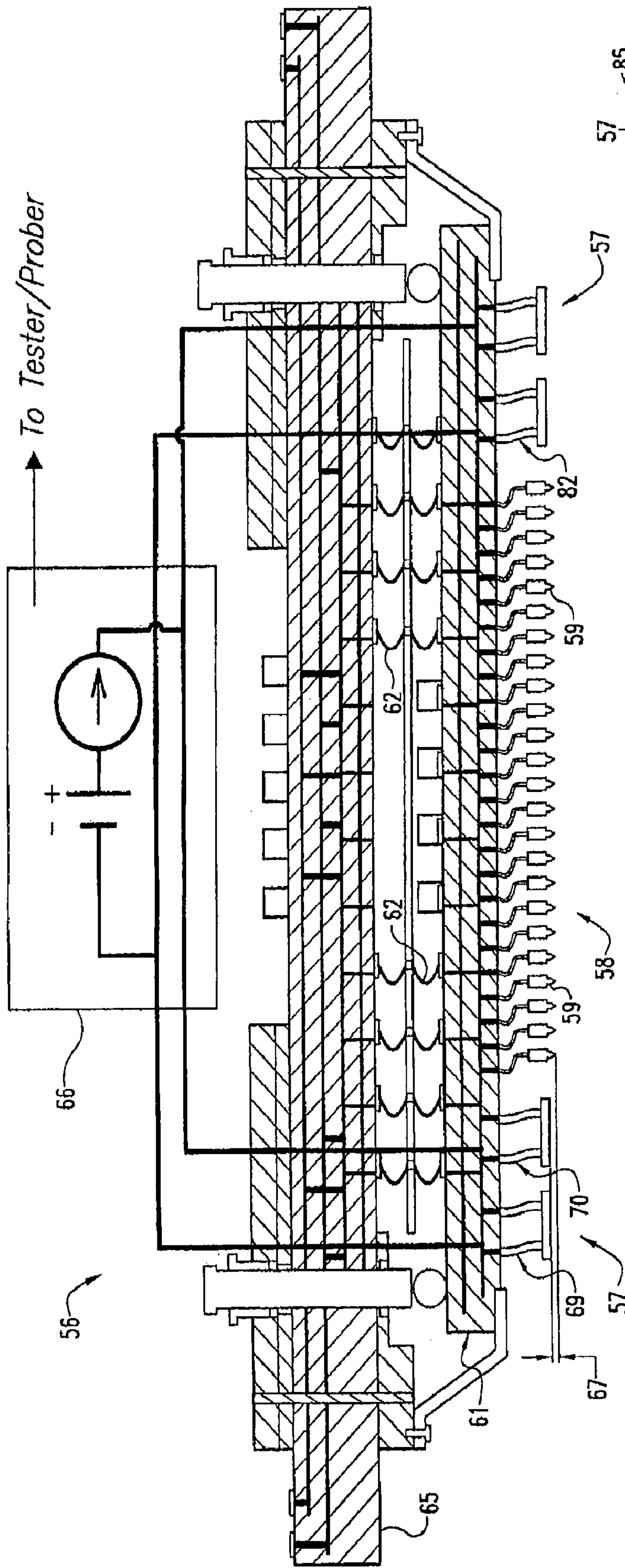

Fig. 8

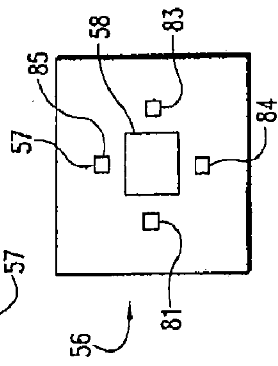

Fig. 9

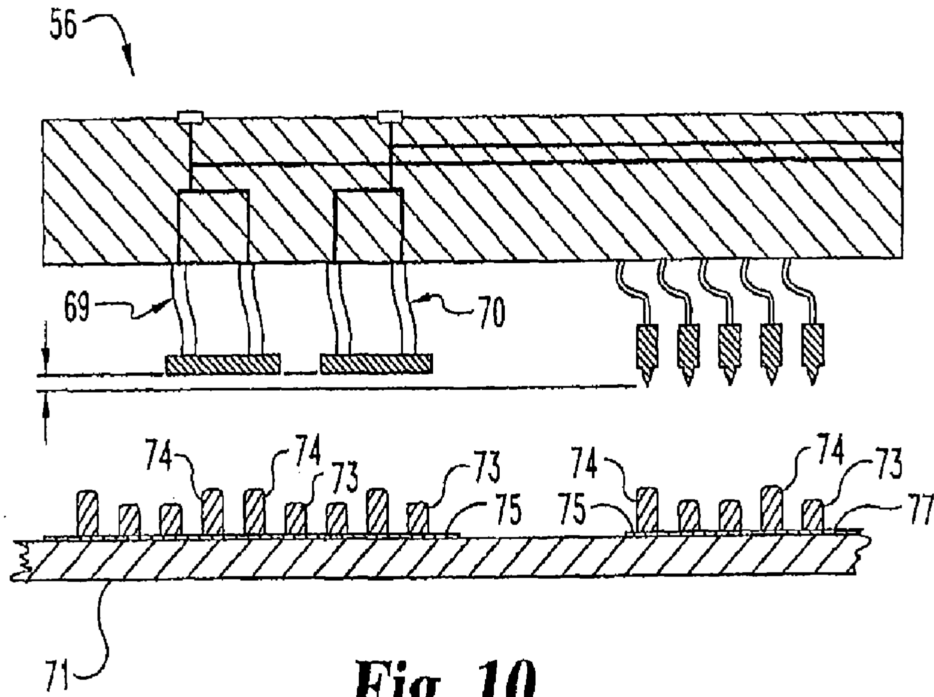

Fig. 10

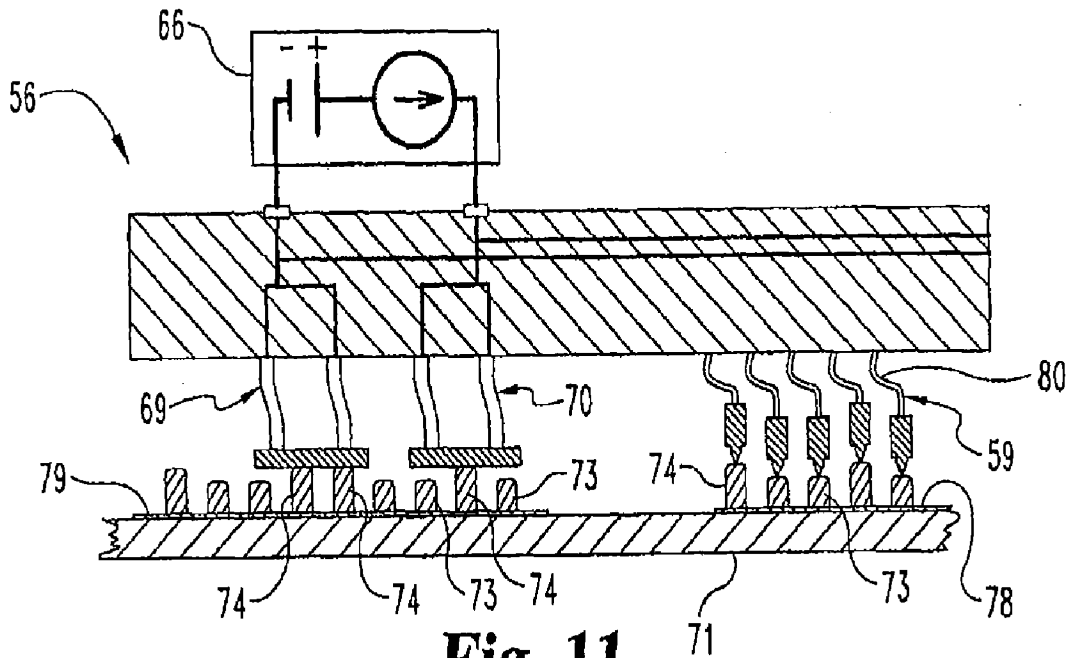

Fig. 11

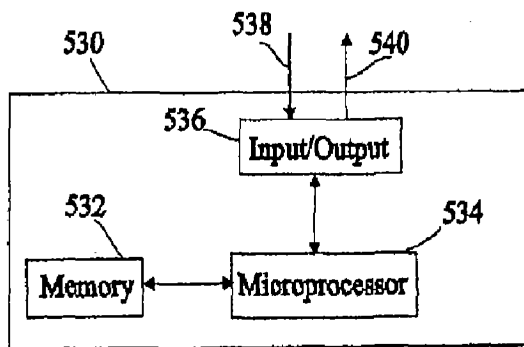

Fig. 12

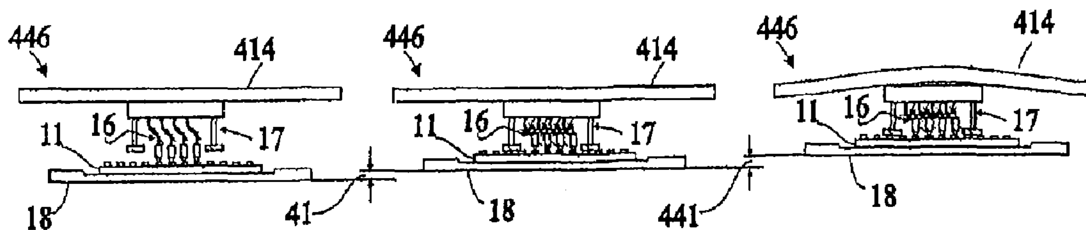

Fig. 15a Fig. 15b Fig. 15c

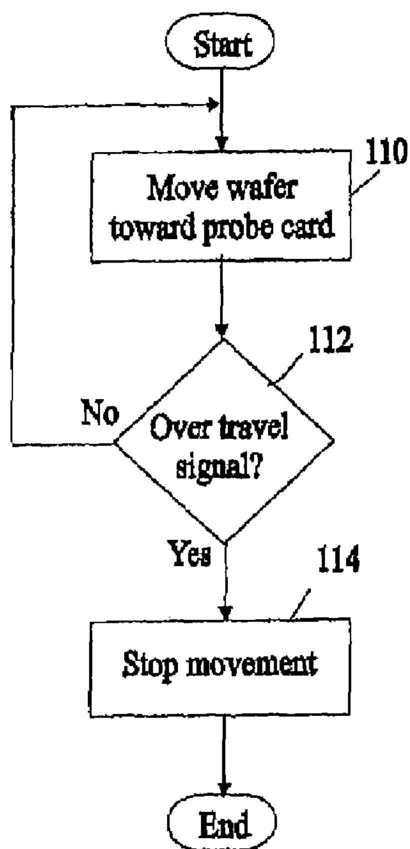

Fig. 13

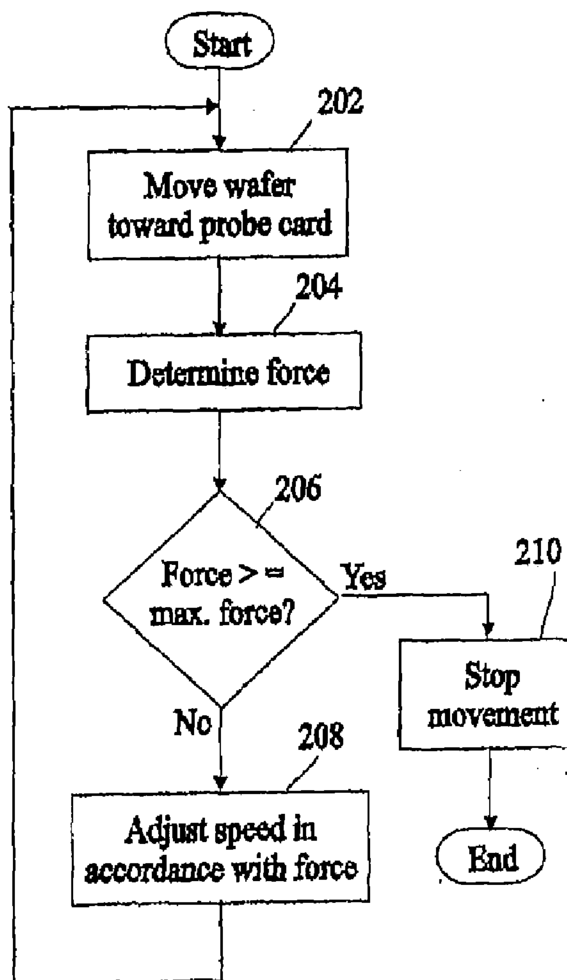

Fig. 14

APPARATUS AND METHOD FOR LIMITING OVER TRAVEL IN A PROBE CARD ASSEMBLY

FIELD OF THE INVENTION

[0001] The present invention relates to testing semiconductor devices.

BACKGROUND OF THE INVENTION

[0002] Individual semiconductor (integrated circuit) devices (dies) are typically produced by creating several identical devices on a semiconductor wafer using known techniques of photolithography, deposition, diffusion and the like. These processes are intended to create a plurality of fully functional integrated circuit devices, after which the individual dies are singulated (severed) from the semiconductor wafer. In practice, physical defects in the wafer itself and/or defects in the processing of the wafer often lead to some of the dies being "good" (fully functional) and some of the dies being "bad" (non-fully functional). It is generally desirable to be able to identify which of the plurality of dies on the wafer are good dies prior to their packaging (encapsulation within a transfer-molded plastic, ceramic or metal package for subsequent integration into a circuit), and preferably prior to their being singulated from the wafer. To this end, a wafer tester or "prober" is used to make a plurality of discrete pressure connections to a like plurality of discrete connection pins (or bond pads) on the dies, In this manner, the semiconductor dies can be tested and exercised prior to singulating the dies from the wafer. A conventional component of a wafer tester is a probe card assembly. In use, the wafer or device under test (DUT) and the probe card assembly are brought together so that the outboard tips of a plurality of probe elements are brought into electrical engagement with corresponding die pads on the wafer.

SUMMARY OF THE INVENTION

[0003] The present invention relates generally to testing semiconductor devices. In one aspect, the invention relates to over travel stops for limiting over travel of a device to be tested with respect to probes of a probe card assembly. Other aspects of the invention include feedback control of relative movement of the device and the probe card assembly and a probe card assembly with a flexible base for absorbing excessive over travel of the device with respect to the probe card assembly.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] FIG. **1** is a side, partially cross-sectional, partially diagrammatic view of a semiconductor tester **5** with probe card assembly **10** positioned to engage with a semiconductor device **11** ("DUT") in accordance with an exemplary embodiment of the present invention.

[0005] FIG. **2** is a side, partially cross-sectional view of the probe card assembly **10** of FIG. **1** shown in engagement with DUT **11**.

[0006] FIGS. **3***a*-**3***f* are side, cross-sectional views showing, in stages, the fabrication of probe tips **21** and stop plates **23**.

[0007] FIGS. **4***a*-**4***c* are side, partially cross-sectional views showing, in stages, fabrication and assembly of space transformer assembly **40**.

[0008] FIG. **5** is a bottom view of the probe card assembly **10** of FIG. **1**.

[0009] FIG. **6** is a side, partially cross-sectional view of a probe card assembly **45** positioned to engage with a semiconductor device **11** ("DUT") in accordance with an alternative embodiment of the present invention.

[0010] FIG. **7** is a side, partially cross-sectional view of the probe card assembly **45** of FIG. **6** shown in engagement with DUT **11**.

[0011] FIG. **8** is a side, cross-sectional and partially diagrammatic view of a probe card assembly **56** in accordance with another embodiment of the present invention.

[0012] FIG. **9** is a plan, diagrammatic view of the probe card assembly **56** of FIG. **8**.

[0013] FIG. **10** is a side, cross-sectional view of a portion of probe card assembly **56** of FIG. **8** and positioned to engage with a wafer **71**.

[0014] FIG. **11** is a side, cross-sectional view of the probe card assembly **56** of FIG. **10** and shown in engagement with wafer **71**.

[0015] FIG. **12** illustrates an exemplary microprocessor based controller.

[0016] FIGS. **13** and **14** illustrate exemplary processes for controlling movement of a wafer into contact with a probe assembly.

[0017] FIGS. **15***a*-**15***c* illustrate a probe card assembly with a flexible base.

DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0018] For the purposes of promoting an understanding of the principles of the invention, reference will now be made to the embodiments illustrated in the drawings and specific language will be used to describe the same. It will nevertheless be understood that no limitation of the scope of the invention is thereby intended, and any alterations or modifications in the illustrated device, and any further applications of the principles of the invention as illustrated therein are contemplated as would normally occur to one skilled in the art to which the invention relates.

[0019] Referring to FIG. **1**, there is shown a semiconductor tester **5** for testing semiconductor devices. Tester **5** generally includes a probe card assembly **10**, support structure **12**, control apparatus **13** and a semiconductor device holder **18**. Probe card assembly **10** is shown positioned to engage with and test a semiconductor device **11** (otherwise known as a device under test or "DUT") in accordance with the present invention.

[0020] The exemplary probe card assembly **10** illustrated in FIG. **1** generally includes a base assembly **14**, a space transformer **15**, a plurality of probes **16** (eight of many shown), and a plurality of overtravel stop assemblies **17**. Support structure **12** supports probe card assembly **10** and can be operable to move probe card assembly **10** toward DUT **11** or to hold probe card assembly **10** stationary while DUT **11** is moved toward probe card assembly **10**. Holder **18** is connected with support structure **12** and is configured to hold DUT **11** stationary during the testing procedure while probe card assembly **10** is moved toward DUT **11** or to move DUT **11** toward probe card assembly **10**. Semiconductor device holder **18** can be in any configuration that securely holds semiconductor device **11** during testing. Holder **18** may also be configured to grasp a semiconductor device **11** from an indexing unit, move it into testing position, hold it and/or move it during testing,

and then move it out of tester **5** to an output station. Holder **18** is contemplated in one embodiment to include electronic connection apparatus for electronically connecting or facilitating such connection of semiconductor device **11** with control apparatus **13**. Control apparatus **13** is connected with support structure **12** and DUT holder **18** and includes elements such as computer hardware and software for controlling movement of probe card assembly **10** and/or DUT **11**. In alternative embodiments, control apparatus **13** does not rely on computer components to control movement of probe card assembly **10** and/or DUT **11**, but instead provides any type of manual actuation apparatus including, but not limited to levers, linkages, a rack and pinion mechanism, cables, pulleys and/or similar devices for moving probe card assembly **10** and/or DUT **11**. Control apparatus **13** is also electronically connected with probe card assembly **10** and connectable to DUT **11** (either individually or through holder **18**) to send and receive data testing signals thereto and therefrom.

[0021] Although probe card assembly **10** is illustrated in FIG. I as comprising a base **14** and a space transformer **15**, probe card assembly may be any type of probe card assembly. For example, probe card assembly **10** may be as simple as only a base **14** to which probes **16** and over travel stops **17** are directly attached. As another example, probe card assembly **10** may comprise a more complex assembly of parts, such as the probe card assembly illustrated in U.S. Pat. No. 5,974,662, which is incorporated by reference herein in its entirety. Probes **16** may be any type of probes, including without limitation needle probes, buckling beam probes (e.g., "COBRA" probes), bumps, posts, and spring probes, Nonexclusive examples of spring probes include the spring contacts described in U.S. Patent Application Publication 200210055282 A1, U.S. patent application Ser. No. 09/032,473 (filed Feb. 26, 1998), U.S. patent application Ser. No. 10/262,712 (filed Jul. 24, 2002), U.S. Pat. No. 6,268,015, and U.S. Pat. No. 5,917,707, all of which are incorporated by reference in their entirety herein.

[0022] DUT **11** is a semiconductor wafer on which have been fabricated a plurality of integrated circuit chips or "dice" (not shown). Each individual die has a number of pins or bond pads **19** for providing power, ground, and signals such as data, address, control, etc. to the die. DUT **11** may contain many hundreds of bond pads **19** disposed in close proximity to one another (e.g. 5 mils center-to-center), and the bond pads may be arranged in configurations other than a single row near the edge of the die. Because of the close proximity of many bond pad arrays, the tips of probes **16** may often need to be spaced more closely to one another (relatively fine pitch) than the connections to their base assembly **14**. "Space transforming" (sometimes referred to as "pitch spreading") may therefore be incorporated in the present application by a space transformer, representatively shown at **15** (comparable to element 506 in the U.S. Pat. No. 5,974,662 patent). Space transformer **15** facilitates making a reliable testing connection between the plurality of probes **16** and the corresponding bond pads **19** of DUT **11** by redirecting spatially indiscriminate input connections (not shown) from base assembly **14** to a specifically organized array of probes **16** that align with the mating array of bond pads **19** as shown, for example, in FIG. **1**. The input connections (not shown) from base assembly **14** to space transformer **15** may be formed in any suitable manner.

[0023] Each of the exemplary plurality of probes **16** includes a resilient interconnecting wire element **20** and a probe tip **21**. Each exemplary over travel stop assembly **17** includes a pair of substantially rigid posts **22** and a stop plates **23**. Each post **22** is rigidly mounted in any suitable manner at one end to space transformer **15**, and at its opposing end is mounted to a stop plate **23**. As DUT **11** and probe card assembly **10** are brought together and probe tips **21** engage with corresponding bond pads **19**, the resilient, spring-like wire elements **20** deform (as shown in FIG. **2**). The neighboring over travel stop assemblies **17** engage DUT **11** at a predetermined distance (a proximity limit) to physically limit how close DUT **11** and probe card assembly **10** can get, and consequently to ensure the proper pressure engagement between probe tips **21** and bond pads **19**.

[0024] Referring to FIGS. **3***a*-**3***g* and **4***a*-**4***c*, there is shown an exemplary method for making a portion of probe card assembly **10** in accordance with one embodiment of the present invention. As shown in FIG. **3***a*, a plurality of pits **26** are etched in a sacrificial substrate **27**, such as a semiconductor wafer, using known methods such as masking. The number and arrangement of pits **26** correspond to the number and arrangement of bond pads on the corresponding DUT to be tested, These pits **26** will form the ends **28** of probe tips **21**. Referring to FIG. **3***b*, an optional first mask layer (mask **31**) is formed, using known methods, over sacrificial substrate **27**, proximal to pits **26**, and in a specific size and shape. Mask **31** is preferably a photoresist material, such as SU8.

[0025] Referring to FIG. **3***c*, a release (and/or seed) material **32** is formed over the substrate and mask **31**. Release material **32** is applied to facilitate separation between sacrificial substrate **27** and mask **31** thereunder and the probe tips **21** and stop plates **23** formed on top thereof. Also, if the probe tips **21** and stop plates **23** are formed by electroplating, release material **32** will provide the conductive layer necessary for electroplating. In one embodiment, release material **32** comprises aluminum. Other appropriate materials may be used for release material **32** including, but without limitation, copper, titanium, tungsten or alloys of these and/or other materials including materials made of two or more layers of such materials that function as described above. For purposes of illustration, the dimensions of certain elements shown in the figures may be exaggerated or not in proportion.

[0026] Referring to FIG. **3***d*, a second mask layer (mask **33**) is formed in a specific pattern over sacrificial substrate **27**, mask **31** and release material **32**, as shown. Mask **33** defines a plurality of cavities **35** and **36** that are sized and shaped to create probe tips **21** and stop plates **23**, respectively. A preferably conductive material is then deposited into cavities **35** and **36** to form probe tips **21** and stop plates **23**, as shown in FIG. **3***e*. The material used to form tips **21** and plates **23** is generally desired to be conductive, non-oxidizing, and chemically non-reactive. Examples of appropriate materials include, without limitation, palladium, gold, rhodium, nickel, cobalt, silver, platinum, conductive nitrides, conductive carbides, tungsten, titanium, molybdenum, rhenium, indium, osmium, rhodium, copper, refractory metals, and their alloys as well as alloys of these and/or other materials. Any appropriate method may be used to deposit such material into cavities **35** and **36** such as, but without limitation, chemical vapor deposition, physical vapor deposition, sputtering, electroless plating, electron beam deposition, and thermal evaporation. Alternatively, a non-conductive material may be used for either or both of probe tips **21** and stop plates **23** such as aluminum oxide, aluminum nitride, etc. In the event a non-conductive material is used for probe tips **21**, at least the ends **28** of tips **21** must be made conductive and must be electri-

cally connected to wire elements **20**. This may be done in any suitable manner such as, and without limitation, by coating the exterior surface of probe tips **21** with a conductive material. After formation of probe tips **21** and stop plates **23**, mask **33** is removed to expose the probe tips **21** and stop plate **23**, as shown in FIG. **3***f*. Because the tips **21** and stop plates **23** are formed lithographically, they may be formed with relatively precise spatial relationships to each other.

[0027] Referring to FIG. **4***c*, the assembly **36** of probe tips **21** and stop plates **23** of FIG. **3***f* are shown having been connected to space transformer **15**. More specifically, interconnecting wire elements **20** connect probe tips **21** to space transformer **15** to form the plurality of probes **16**, and stop plates **23** are connected to and a fixed distance from space transformer **15** by posts **22** to form over travel stop assemblies **17**. In one embodiment, such wire elements are formed and connected to space transformer **15** using the wire bond technique wherein each wire is made of a relatively soft, malleable material and is bonded in a known manner, at the desired location, to space transformer **15** (FIG. **4***a*). Posts **22** may be formed in like manner, but may be thicker to be rigid and/or made of a material that is more rigid. The wire may then be overcoated with a harder, resilient material. Exemplary descriptions of this technique are provided in U.S. Pat. Nos. 5,476,211, 5,917,707, and 6,336,269, which are hereby incorporated by reference.

[0028] Alternatively, elements **20** need not be wires. For example, elements **20** may be resilient spring-like structures formed lithographically by applying and patterning a masking layer to space transformer **15** and then depositing material in the openings in the masking layer or layers as generally illustrated in FIGS. **3***b* and **3***e* above. Indeed, elements **20** may be fashioned in a variety of shapes by molding the masking layer(s) to have the negative of the desired shape (an example of this technique is as described in U.S. Patent Application Publication 2002/0055282 A1, which is incorporated in its entirety herein by reference) or by using multiple masking layers with different patterned openings to define the negative of the desired shape of elements **20** (an examples of this technique are described in U.S. patent application Ser. No. 09/032,473 (filed Feb. 26, 1998) and U.S. Pat. No. 6,268,015, both of which are also incorporated in their entirety herein by reference). Alternatively, such lithographic techniques may be used to build elements **20** over the tips **21** and posts **22** over stop plates **23** following the step illustrated in FIG. **3***e*. All of the foregoing techniques may also be used to make posts **22**.

[0029] As should be apparent from the foregoing, the invention is not limited to any particular type of probe. Rather, the present invention contemplates use of any appropriate probe including, without limitation, needle probes, buckling beam probes (e.g., "COBRA" probes), bumps, posts, and spring probes, examples of which are discussed above. Moreover, the probes may be made and assembled into an array in any manner. For example, probes may be made lithographically, by machining, by stamping, by molding, by microelectrical mechanical system (MEMS) processes, etc. and then assembled into an array. An example in which probes are made using a MEMS process and then assembled into an array is discussed in U.S. patent application Ser. No. 10/262,712 (filed Jul. 24, 2002), which is incorporated in its entirety herein by reference.

[0030] The stop structures may also be made and assembled in of the foregoing ways. Typically, posts **22** are made with sufficient rigidity that, upon engagement of over travel stop assemblies **17** with DUT **11**, posts **22** will not significantly deform and will physically stop further travel of DUT **11** toward probe card assembly **10**.

[0031] Referring again to the example illustrated in FIGS. **3***a*-**4***b*, as shown in FIG. **4***b*, the assembly **38** (FIG. **4***a*) of wire elements **20** and posts **22** extending from space transformer **15** is then brought together with the assembly **36** (FIG. **3***f*) of probe tips **21** and stop plates **23** formed upon on sacrificial substrate **27**. As shown, probe tips **21** and stop plates **23** are all sized and located on sacrificial substrate **27**, and wire elements **20** and posts **22** are all sized and located on space transformer **15**, so that each probe tip **21** aligns with a corresponding wire element **20** and each stop plate **23** aligns with a corresponding pair of posts **22**. Probe tips **21** are then permanently bonded to wire elements **20**, and stop plates **23** are permanently bonded to posts **22**. Such bonding may be performed in any appropriate manner such as, and without limitation, soldering or brazing. Such connection methods are described with reference to FIGS. **8**D and **8**E in the U.S. Pat. No. 5,974,662 patent.

[0032] Following connection of the probe tips **21** and stop plates **23** to wire elements **20** and posts **22**, respectively, sacrificial substrate **27** is removed by any appropriate method such as, but without limitation, etching or dissolving. The resulting space transformer assembly **40** may be joined with other components to form a probe card assembly **10**, such as the probe card assembly shown in FIG. **5** of the U.S. Pat. No. 5,974,662 patent.

[0033] In use, when DUT **11** and probe card assembly **10** are brought together and probe tips **21** engage with corresponding bond pads **19**, the resilient, spring-like wire elements compress or deform (as shown in FIG. **2**). To ensure that DUT **11** moves close enough to probe card assembly **10** to allow all of probes **16** to deform and achieve a sufficiently resistive spring force and thus reliable pressure contact with their corresponding bond pads **19**, neighboring over travel stop assemblies **17** engage DUT **11** at a predetermined distance of travel to physically preclude additional over travel. With probe card assembly **10** constructed as described and shown in FIG. **1**, the combined depth of pits **26** and the thickness of mask **31** corresponds to the over travel distance **41** (FIG. **1**) permitted by the present invention.

[0034] The probe card assembly **10** of FIG. **1** shows just eight probes **16** and a pair of neighboring stop assemblies **17**. Another configuration is shown in FIG. **5** where the probe card assembly **42** (bottom view) has two arrays **43** and **44**, each containing **48** probes **16** extending downwardly from space transformer **15**, and where there are six over travel stop assemblies **17** spaced around the outside of the two arrays **43** and **44**. It is contemplated that probe card assembly **42** or a similar probe card assembly may be used to test DUT's with fewer bond pads **19** than are contained in the corresponding array(s) of probes **16**. Such excess probes **16** that do not contact a corresponding bond pad (or an inactive bond pad) can be deselected by software.

[0035] The test system in which the probe card assembly of the present invention is incorporated may operate to move DUT II toward a stationary probe card assembly **10** or to move probe card assembly **10** toward a stationary DUT **11** or to move both DUT **11** and probe card assembly **10** towards each other. Further, such test system may be configured for such movement by the DUT **11** and/or probe card assembly **10** to be effected manually or automatically. It is contemplated that such test system will incorporate any appropriate

configuration of machinery, computer hardware and software to effect such manual or automatic movement, to provide for adjustment of the limits, path and rate of such movement, and to receive, process and display output data produced during such movement and from the engagement between the DUT and the probe card assembly.

[0036] Alternative embodiments are contemplated wherein there are more or less than two posts **22** connecting and holding each stop plate **23**. Alternative embodiments are contemplated wherein plates **23** are in shapes other than the relatively planar and rectangular configuration shown. Alternative embodiments are contemplated wherein posts **22** are not rigid, but instead are somewhat resilient to provide a degree of "give" or "compliance" when DUT **11** engages with over travel stop assemblies **17**. For example, as shown in FIG. **6**, a probe card assembly **45** is shown in accordance with another embodiment of the present invention wherein the stop plates **46** and **47** of over travel stop assemblies **48** and **49** are held by resilient posts **50**. (Like probe card assembly **10** of FIG. **1**, the probe card assembly **45** shows just eight probes **16** and just two over travel stop assemblies **48** and **49**. The invention contemplates any number of probes and stop assemblies to properly engage with the bond pads of a DUT **11** to be tested). Posts **50** may be formed and connected to space transformer **15** using any appropriate method, including those techniques discussed herein for forming and connecting wire elements **20**.

[0037] One benefit of making posts **50** resilient is realized in the event that DUT **11** is at all non-planar, that any of stop plates **46** and **47** are or have become non-planar, that stop plates **46** and **47** of over travel stop assemblies **48** and **49** are or have become mutually non-planar, and/or that DUT **11** is not parallel to the plane of the stop plates **46** and **47** at the moment of engagement therewith. Thus, referring to FIG. **7** where, in exaggerated fashion, DUT **11** is shown to be non-planar at the moment of initial engagement, the resiliency of posts **50** allows the first stop plate **46** to engage, and its resilient posts will deform until the other stop plate **47** likewise engages. The resiliency of posts **50** is selected to permit such deformation by one or a few of the posts when necessary, but to also still provide a physical over travel limit when all the over travel stop assemblies **48** are engaged, Alternative embodiments are contemplated where posts **50** are made to be both rigid and resilient. That is, a portion of each post **50** is made resilient to enable a limited degree of give (as shown in FIG. **7**) and another portion of each post is made rigid to define the maximum limit of give, and thus overtravel. Alternative embodiments are also contemplated wherein plates **23** are not rigid, but instead are somewhat resilient to provide a degree of "give" or "compliance" when DUT **11** engages with over travel stop assemblies **17**.

[0038] Alternative embodiments are contemplated wherein one or more over travel stop assemblies are wired to provide a signal that the corresponding DUT **11** has been engaged. Such signal may simply indicate engagement or may signal the extent of engagement (e.g., by signaling a degree of force exerted by the wafer on the probes or the over travel stop). For example, such signal may provide a binary output x: no contact (x=0), contact (x=1). Alternatively, a more detailed response may be provided by the output value x: no contact (x=0), contact ($0<x\leqq 1$) where any x greater than 0 indicates contact and the value of x greater than 0 and less than or equal to 1 indicates the extent of travel of the DUT from initial contact up to and including the limit of travel. Such output signal is contemplated to be received as input by computer components connected with the probe card assembly and displayed in any appropriate form and/or used to further control the overall probe testing operation. Typically, such output signal would be sent to the tester or prober, which would then stop movement of the probe card assembly toward the semiconductor wafer when the desired over travel limit is reached.

[0039] An example of such assembly in shown in FIG. **8**, where a probe card assembly **56** includes over travel stop assemblies **57** that are wired to provide over travel position output signals. Like probe card assembly **45** of FIG. **6** and similar to the probe card assembly **500** of FIG. **5** of the U.S. Pat. No. 5,974,662 patent, probe card assembly **56** includes an array **58** of probes **59** and over travel stop assemblies **57** mounted to a spaced transformer **61**, which is electronically connected by various interconnection wire elements **62** and an interposer **63** to a probe card assembly **65**, An over travel control unit **66** is wired to the over travel stop assemblies **57** whereby the over travel output signals are transmitted to control unit **66**, which transmits corresponding signals to the tester/prober (not shown). The allowable over travel is indicated at **67**. FIG. **9** is a plan view of the probe card assembly **56** showing diagrammatically one exemplary placement of over travel stop assemblies **57** relative to the array **58** of probes **59**.

[0040] FIGS. **10** and **11** illustrate one exemplary arrangement for detecting completion of a desired amount of over travel of bond pads or pins **73**, **74** of wafer **71** with respect to probes **59**. Referring to FIG. **10**, the over travel stop assemblies **57** are arranged in adjacent pairs. Thus, at each of the four sites of the probe card assembly **56** of this embodiment (FIG. **9**), probe card assembly **56** includes a pair of over travel stop assemblies **69** and **70**. In each die on the wafer **71** to be tested, the bond pads or pins **73**, **74** comprise functioning pins **73** and dummy pins **74**. (Pins **73**, **74** in FIGS. **10** and **11** are shown as having slightly different heights due to inherent manufacturing imprecision.) Functioning pins **73** are functional in providing the desired power, ground and signal capabilities for their corresponding die **76** (or **77**), while dummy pins **72** are shorted to ground.

[0041] In use, when wafer **71** and probe card assembly **56** are brought together, probe tips **59** will engage with corresponding pins on the DUT **11** (device under test) **78**. Because of the resiliency of the wire element **80** of each probe **59**, each probe **59** will deform as necessary and engage with each of its corresponding pins **73** and **74**. It should be noted that there may or may not be a probe **59** that corresponds to a particular dummy pin **74**. It should also be noted that the contact plates of over travel assemblies **69** and **70** are preferably made to correspond to known locations of dummy pins **74** on wafer **71**. A circuit will be completed and a corresponding signal will be generated and transmitted through control unit **66** to the prober/tester (not shown), and movement of probe card assembly **56** toward wafer **71** will stop. The invention contemplates that the system software will be configured to control the testing operation in response to any desired contact combination. That is, in one embodiment, contact by any two adjacent over travel stop assemblies (i.e. **69** and **70**) with dummy pins will cause movement of probe card assembly **56** to stop. Alternatively, referring to FIGS. **8** and **9**, any one over travel stop assembly (i.e. **69**) at one side **81** of array **58** and any one over travel stop assembly (i.e. **82**) at another side **83** (or **84** or **85**), can be programmed to stop movement of probe card

assembly **56**. Alternatively, just one over travel stop assembly (i.e. **69**) could be programmed to stop movement of probe card assembly **56**.

[0042] Alternative embodiments are contemplated wherein two or more over travel stop assemblies are wired as above and the output thus indicates which over travel stop assemblies have engaged with the DUT **11** and by how much. Such output, from just one or from a plurality of the over travel stop assemblies, is contemplated to be made available for display or other recognition by a human or machine. Thus, such output may simply be indicated by a single LED flashing or by a buzzer. Alternatively or in addition, a display screen may diagrammatically indicate the entire probe card assembly layout and show by any appropriate display which over travel stop assemblies have been engaged and by how much. Alternatively or in addition, the output signal may be received by a computer or other machine and acted upon. For example, a signal that an over travel stop assembly has engaged a bond pad or pin may cause the system to cease movement of the probe card assembly toward the DUT **11**, or visa versa, or movement for only another pre-programmed distance. Where the output signal indicates the extent of engagement, such information can be used by the human user or the machine to adjust the limits of movement of the DUT relative to the probe card assembly, as well as the rate of such movement.

[0043] FIGS. **13** and **14** illustrate exemplary methods for automatically controlling movement of a wafer to be tested into contact with a probe card assembly, and FIG. **12** illustrates a feedback controller **530** that may implement any of the processes of FIGS. **13** and **14**. The exemplary feedback controller **530** illustrated in FIG. **12** is a microprocessor based controller and may be, for example, part of control apparatus **13**. As shown, it includes a digital memory **532**, a microprocessor **534**, and an input/output port **536**. Input data **538** is received and output data **540** is output through input/output port **536**. The digital memory **532** may be any type of memory including an electronic memory, an optical memory, a magnetic memory, or some combination of the foregoing. As just two examples, digital memory **532** may be a read only memory, or digital memory **532** may be a combination of a magnetic or optical disk and a random access memory. Microprocessor **534** executes instructions (which may be in the form of software or microcode) stored in digital memory **532**.

[0044] The exemplary methods illustrated in FIGS. **13** and **14**, which may be implemented in software and executed on a microprocessor based system such as the one illustrated in FIG. **12**, will be explained with reference to a probe card assembly **56** such as the one illustrated in FIGS. **8-11** in a tester **5** like the one illustrated in FIG. **1**. For purposes of discussion only, it is assumed that a wafer such as exemplary wafer **71** is moved while probe card assembly **56** is held stationary. Of course, the wafer could alternatively be held stationary and probe card assembly moved, or both the wafer and the probe card assembly could be moved. The wafer **71** may be supported by any appropriate means, such as the wafer holder **18** illustrated in FIG. **1**, which itself is moved by any appropriate means, such as an electric motor (not shown). Output data **540** (FIG. **12**) includes signals that control movement of the wafer **71** (e.g., by moving the wafer holder **18**), and input data **538** includes signals from over travel control unit **66** or other sensors (e.g., the output of over travel control unit **66** may be directed to feedback controller **530** as input data **538**).

[0045] The exemplary method illustrated in FIG. **13** utilizes one or more sensors for detecting when the wafer **71** has been moved into contact with the probes **71** and then further moved by a desired amount of over travel past first contact. For illustration purposes, the sensor(s) is assumed to comprise over travel stop assemblies **69**, **70** wired to detect contact as illustrated in FIGS. **10** and **11**. It should be understood, however, that any sensor for detecting or estimating when the wafer **71** has been moved the desired over travel distance may be used. Such sensors include by way of example acoustic sensors, optical sensors, etc., which may be used to detect, for example, when the over travel stops reach a particular position. It should also be noted that one to several such sensors may be used, and if a plurality of sensors are used, the sensors may be arranged in any pattern on probe card assembly **56**. The pattern of four sensors **81**, **83**, **84**, **85** illustrated in FIG. **9** is but one exemplary pattern.

[0046] Turning now to the exemplary method illustrated in FIG. **13**, this exemplary method begins after wafer (e.g., wafer **71** shown in FIGS. **10** and **11**) has been placed on a moveable holder (e.g., wafer holder **18** illustrated in FIG. **1**), and pads or pins **73**, **74** of wafer have been aligned with probes **59**, as illustrated in FIG. **10**. As shown in FIG. **13**, the first step **110** is to move the wafer **71** toward the probe card assembly **56**. At step **112**, it is determined whether the pins **73**, **74** on wafer **71** have been moved into contact with probes **59** and over traveled the desired distance. If no, movement of the wafer **71** toward the probe card assembly **56** continues (step **110**). If yes, movement of the wafer **71** is stopped at step **114**.

[0047] Determining whether pins **73**, **74** have reached the desired over-travel (step **112**) may be detected or estimated in any way. As just one example, stop structures **69**, **70**, such as those illustrated in FIGS. **10** and **11** may be configured so that an over travel sensor **66** generates a signal when over travel stops **69**, **70** contact pins **73**, **74**. That signal may be input to controller **530** as input signal **538**. As mentioned above, other types of sensors may be used. Also, any number of sensors may be used, and if multiple sensors are used, they may be positioned in any suitable pattern. If multiple sensors are used, a signal indicating that the desired amount of over travel has been reached may be triggered by any one or more of the sensors in any desired pairing or sequence. For example, referring to the exemplary pattern of sensors **81**, **83**, **84**, **85** shown in FIG. **9**, a over-travel-reached state may be found to be affirmative at step **112** when any one of the sensors **81**, **83**, **84**, **85** is activated. As another nonexclusive example, the over-travel-reached state may be found to be affirmative at step **112** only after all four sensors **81**, **83**, **84**, **85** are activated. As another example, the over-travel-reached state may be found at step **112** after a pair of sensors (e.g., opposite pairs **81**, **83**, or pairs **84**, **85**) are activated. Many other combinations are possible.

[0048] Turning now to the exemplary method illustrated in FIG. **14**, this exemplary method also begins after a wafer (e.g., wafer **71** shown in FIGS. **10** and **11**) has been placed on a moveable holder (e.g., wafer holder **18** illustrated in FIG. **1**), and pads or pins **73**, **74** of wafer **71** have been aligned with probes **59**, as illustrated in FIG. **10**. As shown in FIG. **14**, the first step **202** is to move the wafer **71** toward the probe card assembly **56** at an initial speed. During this movement, the force the wafer pads or pins **73**, **74** exert against probes **59** is determined at step **204**, and it is determined at step **206** whether the force exceeds a predetermined maximum force.

(Of course, before first contact between the pads or pins **73**, **74** and probes **59**, the force is zero.) If yes, movement of the wafer **71** toward the probe card assembly **56** is stopped at step **210** (e.g., controller **530** issues control signals **540** that cause movement to stop). If, however, the determined force is less than the maximum force (step **206**), at step **206**, the speed of the movement of the wafer **71** toward the probe card assembly **56** is adjusted in accordance with the force determined at step **204** (e.g., again the controller **530** issues control signal(s) **540** that adjusts the speed). Preferably, the speed is decreased as the force increases. The steps of moving the wafer **71** toward the probe card assembly **56** (step **202**), determining the force **204**, and adjusting the speed of the wafer **71** (step **208**) are repeated until the force on the probes **56** exceeds the maximum force (step **206**). It should be noted that step **208** is optional. That is, the process of FIG. **15** can be performed without adjusting the speed following a negative determination at step **206**.

[0049] Again, there are many different types of sensors that may be used to determine or estimate the force on a probe. For example, over travel stops **69**, **70** may be fitted with force measuring sensors (e.g., a piezoelectric material). Alternatively, force measuring device(s) may be connected directly to one or more probes **59**. Also, one or more such sensors may be used. If more than one is used, the step of determining the force **204** may comprise averaging the forces detected by all of the sensors.

[0050] FIGS. **15***a*-**15***c* illustrate a probe card assembly **446** in which base **414** is made of a flexible material. As will be seen, because the base **414** is flexible, it absorbs extra over travel, As shown in FIG. **15***a,* wafer holder **18** brings wafer **11** into first contact with probes **16**. As shown in FIG. **15***b,* wafer holder **18** moves wafer **11** past the point of first contact by an over travel distance **41**. As shown in FIG. **15***c,* for whatever reason, wafer holder **18** moves wafer **11** beyond the desired over travel **41** by an additional over travel distance **441**. Normally, the additional over travel **441** could cause excessive forces to be exerted on the over travel assemblies **17** and possibly the probes **16**. As also shown in FIG. **16***c,* however, the base flexes, absorbing all or at least part of the additional over travel **441**, eliminating or at least reducing the excessive forces caused by the additional over travel **441**. The base **414** may be made of any material that is sufficiently rigid to support probes **16** but sufficiently flexible to absorb all or part of over travel **441**. Examples of such materials include, without limitation, printed circuit board material, Mylar, organic materials, rubbers, and plastics.

[0051] While the invention has been illustrated and described in detail in the drawings and foregoing description, the same is to be considered as illustrated and not restrictive in character, it being understood that only the preferred embodiment has been shown and described and that all changes and modifications that come within the spirit of the invention are desired to be protected.

1-28. (canceled)

29: A method of controlling relative movement between an electronic device to be tested and a probe card assembly, said method comprising:
- effecting relative movement of said device and said probe card assembly;
- detecting a desired amount of over travel between said wafer and said probe card assembly; and
- upon detecting said desired amount of over travel, stopping said relative movement of said device and said probe card assembly.

30: The method of claim **29**, wherein said detecting said desired amount of over travel comprises detecting contact between a stop structure on said probe card assembly and said device.

31: The method of claim **29**, wherein said detecting said desired amount of over travel comprises detecting contact between a plurality of stop structures on said probe card assembly and said device.

32: A media for storing machine-executable instructions for causing a controller to perform a method of controlling relative movement of a device to be tested and a probe card assembly, said method comprising:
- generating a control signal to effect relative movement of said device and said probe card assembly;
- receiving an input signal indicating completion of a desired amount of over travel between said wafer and said probe card assembly; and
- in response to said input signal, generating a control signal to stop said relative movement of said device and said probe card assembly.

33: A method of controlling relative movement between an electronic device to be tested and a probe card assembly, said method comprising:
- effecting relative movement of said device and said probe card assembly;
- determining a force of said device against said probe card assembly; and
- stopping said movement when said force exceeds a maximum force.

34: The method of claim **33** further comprising. adjusting a speed of said movement in accordance with said force.

35: The method of claim **34**, wherein said adjusting a speed of said movement in accordance with said force comprises decreasing said speed as said force increases.

36: A media for storing machine-executable instructions for causing a controller to perform a method of controlling relative movement of a device to be tested and a probe card assembly, said method comprising:
- generating a control signal to effect relative movement of said device and said probe card assembly;
- receiving an input signal corresponding to a force of said device against said probe card assembly; and
- generating a control signal to stop said movement when said force exceeds a maximum force.

37: The media of **36**, wherein said method further comprises generating a control signal to adjust a speed of said movement in accordance with said force.

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