



159159

1

TITLE: CONNECTOR APPARATUS

G00002

CROSS REFERENCE TO RELATED APPLICATIONS

This Application makes use of co-pending applications entitled
5 "COMPLIANT PROBE APPARATUS."

BACKGROUND - FIELD OF THE INVENTION

The invention relates to burn-in and testing of microelectronic devices, specifically to probes for use in socket assemblies suitable for making connections to integrated circuits in single chip or wafer form.

10 BACKGROUND OF THE INVENTION

Microelectronic devices are subjected to a series of test procedures during the manufacturing process in order to verify functionality and reliability. The testing procedures conventionally include wafer probe testing, in which microelectronic device chips are tested to determine operation of each chip
15 before it is diced from the wafer and packaged. Probe cards built of long cantilever wires are used to test one or several chips at a time at the wafer level.

Typically, not all chips on a wafer are found to be operable in the wafer probe test, resulting in a yield of less than 100% good devices. The wafer is diced into individual chips, and the good chips are assembled into packages.
20 The packaged devices are dynamically burned-in by loading into sockets on burn-in boards and electrically operating at a temperature of from 125 °C to 150 °C for a burn-in period of 8 to 72 hours in order to induce any defective devices to fail. Burn-in accelerates failure mechanisms that cause infant mortality or early failure of the devices, and allows these defective devices to be screened
25 out by a functional electrical test before they are used commercially.

2.

A full functional test is done on packaged devices, which are operated at various speeds in order to categorize each by maximum speed of operation. Testing discrete packaged devices also permits elimination of any devices that failed during the burn-in process. Burn-in and test of packaged devices is accomplished by means of sockets specially suited to the burn-in conditions and to high speed testing respectively. Conventional manufacturing processes are expensive and time consuming because of a repeated handling and testing of individual discrete devices through a lengthy set of steps that adds weeks to the total manufacturing time for the device.

A considerable advantage in cost and in process time can be obtained by burn-in and test of the wafer before it is diced into discrete devices. Additional savings can be obtained by fabricating chip size packages on each device on a wafer before the wafer is diced into discrete devices. A considerable effort has been expended by the semiconductor industry to develop effective methods for wafer level packaging, burn-in and test in order to gain benefits of a greatly simplified and shortened process for manufacturing microelectronic devices. In order to reap these benefits, it is necessary to provide means to burn-in and speed test chips before they are diced from the wafer into individual discrete devices.

Conventional cantilever wire probes are not suited to burn-in and speed testing of devices on the wafer. Cantilever wire probes are too long and bulky to allow simultaneous contact to all of the devices on a wafer, as required for simultaneous burn-in of all of the devices on the wafer. In addition, long cantilever wire probes are not suitable for functional testing of high-speed devices because of a high self and mutual inductance of the long, parallel wires comprising the probes.

A small, high-performance probe that can be made at low cost is required for practical application of wafer burn-in and test procedures. To be useful for wafer burn-in and test, the probes must reliably contact all of the pads on the devices under test while they are on the undiced wafer. Probes for contacting the wafer must provide electrical contact to pads on devices where the pads vary in height on the surface of the wafer. In addition, the probes must break through any oxide layers on the surface of the contact pads in order to make a reliable electrical contact to each pad. Many approaches have been tried to provide a cost-effective and reliable means to probe wafers for burn-in and test, without complete success.

A number of attempts have been tried to provide small, vertically compliant probes for contacting reliably the pads on devices on a wafer. According to the invention represented by U.S. Patent No. 4,189,825, to David R. Robillard and Robert L. Michaels, a cantilever probe is provided for testing integrated circuit devices. In FIG. 1, cantilever 28 supports sharp tips 26 above aluminum contact pads 24 on a chip 23. A compliant member 25 is urged downward to move tips 26 into contact with pads 24. An aluminum oxide layer on pad 24 is broken by sharp tip 26 in order to make electrical contact between tip 24 and the aluminum metal of pad 24. The rigidity of small cantilever beams is generally insufficient to apply the force to a tip that is necessary to cause it to break through an aluminum oxide layer on a contact pad, without an external means of applying force to the cantilever. Cantilever beams of glass, silicon, ceramic material, and tungsten have been tried in various configurations, without success in providing burn-in probes of sufficient force and flexibility.

A flexible membrane probe shown in FIG. 2A is described in Flexible Contact Probe, IBM Technical Disclosure Bulletin, October 1972, page 1513. A flexible dielectric film 32 includes terminals 33 that are suited to making electrical contact with pads on integrated circuits. Terminals 33 are connected

to test electronics by means of flexible wires 34 attached to contact pads 35 on terminals 33. Probes fabricated on a flexible polyimide sheet were described in the Proceedings of the IEEE International Test Conference (1988) by Leslie et al. The flexible sheet allows a limited amount of vertical motion to accommodate
5 variations in height of bond pads on integrated circuits on a wafer under test. Membrane probes such as that described by Leslie et al provide connections to integrated circuit chips for high performance testing. However, dimensional stability of the membrane is not sufficient to allow contacts to pads on a full wafer during a burn-in temperature cycle.

10 Fabrication of the contacts on a thin silicon dioxide membrane is shown in FIG. 2B as described in U.S. Patent No. 5,225,771 by Glenn J. Leedy. A silicon dioxide membrane 40 has better dimensional stability than polyimide, thereby somewhat ameliorating the dimensional stability problem of mating to contact pads on a wafer under burn-in test. Probe tips 41 are connected by vias 44
15 through membrane 40 to circuit traces 45 that are linked to an additional layer of circuitry 42 above a dielectric film 43. Limited vertical compliance of the test probes on silicon dioxide membrane 40 renders use of probe arrays unreliable for use in burn-in of devices on a semiconductor wafer.

Fabrication of an array of burn-in probes on a semiconductor wafer is
20 described in U.S. Patent No. 4,585,991, as illustrated in Figs. 3A and 3B showing a top plan view and a sectional view respectively. Probe 51 is a pyramid attached to semiconductor wafer substrate 52 by tabs 54. Material 53 is removed from the semiconductor wafer 52 in order to isolate mechanically the probe 51. A probes as in FIG. 3A provides a limited vertical movement but it
25 does not allow space on the substrate for wiring needed to connect an array of probes to test electronics required for dynamic burn-in.

An approach to providing flexible probes to device contact pads involves the use of flexible wires or posts to connect the test circuitry to the pads. A flexible probe shown in FIG. 4A is described in U.S. Patent No. 5,977,787 by Gobina Das et al. Probe 60 is a buckling beam, earlier generally described in U.S. Patent No. 3,806,801 by Ronald Bove. Probe 60 is adapted for use in burn-in of devices on a wafer. Guides 61 and 62 that hold probe 60 have a coefficient of expansion similar to that of the wafer being tested. The probe tip 63 is offset by a small distance 60 to provide a definite modality of deflection for beam 60. Although buckling beams are well suited to testing individual integrated circuit chips, they are too expensive to be used for wafer burn-in where thousands of contacts are required. Further, electrical performance of buckling beam probes is limited because of the length required for adequate flexure of the beam.

Another approach using flexible posts is shown in FIG. 4B as disclosed in U.S. Patent No. 5,513,430 by Arnold W. Yanof and William Dauksher. FIG. 4b shows flexible probes in the form of posts 66 that are able to bend in response to force on probe tip 67. Posts 66 are formed at an angle to a substrate 69 in order to allow them to flex vertically in response to a force on tip 67 from mating contact pads. Posts 66 have a taper 65 from the base terminal 68 to tip 67 in order to facilitate flexure.

Yet another approach using flexible wires and posts is shown in FIG. 4C as disclosed in U.S. Patent No. 5,878,486 by Benjamin N. Eldridge, et al. The probe shown in FIG. 4C comprises a probe tip 72 on a spring wire 71 that is bent to a specific shape in order to facilitate flexure. Wire 71 is joined to substrate 74 by a conventional wire bond 73. Probes of the type shown in FIG. 4C require a long spring length to achieve the contact force and compliancy needed for wafer burn-in. Additionally, such probes that use individual wires are

too expensive for use in wafer burn-in where many thousands of probes are required for each wafer.

Further approaches to providing flexible probes involve the use of compliant layers interposed between a test head and a device being tested, such that terminals on the test head are electrically connected to mating contact pads on the device. The electrical connector described in U.S. Patent No. 3,795,037 by Willem Luttmmer utilizes flexible conductors embedded in an elastomer material to make connections between mating pairs of conductive lands that are pressed into contact with the top and bottom surfaces of the electrical connector. Many variations of flexible conductors including slanted wires, conductive filled polymers, plated posts and other conductive means in elastomeric material in order to form compliant interposer layers.

The approaches listed above and other attempts have been unsuccessful in providing a high performance probe that allows economical burn-in and speed test of microelectronic devices on a wafer before the wafer is diced into discrete chips.

SUMMARY OF THE INVENTION

In accordance with the present invention, a small compliant probe is disclosed that includes a conductive tip, which is positioned on a supporting surface in a manner that allows a tip on the probe to move flexibly with respect to the supporting surface. The probe tip moves vertically in response to the force of a mating contact pad as it biased against the tip. Mechanical compliance of the probe allows electrical contact to be made reliably between the probe and a corresponding contact pad on a microelectronic device, where the mechanical compliance accommodates variations in height of the contact pad.

It is an object of the present invention to provide a method and means for making electrical connection to contact pads on microelectronic devices on an undiced wafer in order to burn-in the devices before they are diced into separate chips. Compliant probes according to the invention allow reliable electrical connections to be made simultaneously to all of the contact pads arrayed on the surface of a wafer so that microelectronic devices on the wafer can be burned-in economically.

Another object of the present invention is to provide a fixture for burn-in of microelectronic devices on undiced wafers. The fixture electrically connects contact pads on each device to drive circuitry that supplies electrical signals to the device as required during dynamic burn-in at high temperature. Electrical signals and power are supplied to all of the chips on a wafer simultaneously. Mechanical compliance of probes in the fixture accommodates variations in height of the contact pads and in the probe tips such that each probe tip remains in contact with its mating contact pad throughout the temperature cycle of the burn-in process.

Yet another object of the present invention is to provide an electrical probe card that allows high speed testing of unpackaged microelectronic devices. Small, compliant probes as taught in this disclosure are used to make temporary connections to corresponding pads on a device in order to apply electrical test signals to that device and to measure electrical signals from that device. The small size of the compliant probe allows high speed electrical signals to be passed to and from the device without losses due to excessive inductance or capacitance associated with wire probes as used in the prior art.

A further object of the present invention is to provide a method and means for burning-in, testing and operating microelectronic devices where electrical contacts on the device are disposed in an area array over a surface of

the device. Small, compliant probes as taught in this disclosure are used to make reliable electrical connections to contacts on the device, where the contacts are arranged in an area array. Mechanical compliance allows the tip of each probe to maintain electrical contact with a mating contact on the device
5 notwithstanding variations in the height of contacts on the device both at room temperature and at the operating temperature range of the device.

Another object of the present invention is to provide a small socket for connecting integrated circuit chips to electrical circuits for purposes of burn-in, test and operation of the chip. The small size of each probe contact in the
10 socket allows high-speed operation of a chip mounted in the socket. Mechanical compliance of the probes as taught in this disclosure enables reliable electrical connections to be made to a rigid chip with minimal or no packaging. Compliant probes according to the present invention allow construction of small, economical sockets for chip scale packages and for flip-chips.

15 These as well as other objects of the invention can be met by providing a mechanically compliant electrical probe, wherein a probe tip is disposed between the two ends of an elongated thin spring of flexible material. The elongated thin spring is supported above a substrate by posts at each end of the spring, thereby allowing the tip to move flexibly in a vertical direction by bending
20 and stretching of the spring material.

The probe disclosed herein is significantly improved over conventional cantilever probes in that it provides a greater range of compliant motion of the probe tip for any given probe force and probe size. A conventional cantilever probe is limited in the range of motion it provides in response to a given force
25 the elastic limit of the probe material is reached. The maximum mechanical stress in cantilever probes is concentrated on the surface of the cantilever material at the point of flexure. The invention provides a greater range of motion

for a given spring material and probe force, before it reaches the elastic limit of that material.

The invention increases manufacturing efficiency for microelectronic devices by providing test and burn-in functions reliably at the wafer level, while
5 at the same time reducing the size of the test fixture. The mechanically compliant probe provides a large range of motion relative to the size of the probe. This range of motion is important in making connections to a device with contact pads that are not substantially in the same plane. The compliant probe tip moves flexibly to accommodate differences in the height of mating contact
10 pads while maintaining sufficient force of the probe tip on the contact pad to assure reliable electrical contact therebetween.

BRIEF DESCRIPTION OF THE DRAWINGS

The novel features believed characteristic of this invention are set forth in the appended claims. The invention itself as well as other features and
15 advantages thereof will be best understood by reference to the detailed description that follows, read in conjunction with the accompanying drawings wherein:

FIG. 1 shows a sectional view of a cantilever probe of the prior art.

FIGS. 2A and 2B show cross sectional views of flexible membrane
20 probes of the prior art.

FIGS. 3A and 3B show views of a probe fabricated on a silicon wafer of the prior art where FIG. 3A shows a plan top view of the probe and FIG. 3B shows a sectional view of the probe.

FIGS. 4A to 4C show flexible post probes of the prior art.

FIG. 5 shows a view of a compliant probe in accordance with the present invention

FIG. 6 shows a view of an alternate configuration of a compliant probe incorporating a ground plane shield.

5 FIGS. 7A to 7C show an embodiment of a compliant probe where FIG. 7A is a top plan view, FIG. 7B is a sectional view of the probe at rest, and FIG. 7C is a sectional view of the probe when acted upon by force F.

FIGS. 8A to 8D show top plan views of alternative embodiments of a probe designs for a compliant probe according to the present invention.

10 FIGS. 9A to 9D show probe tips used in compliant probe structures according to the present invention.

FIG. 10 shows a view of an embodiment of a compliant probe.

FIG. 11 shows a view of an embodiment of a compliant probe incorporating an elastomeric encapsulation material.

15 FIGS. 12A to 12C show an embodiment of a compliant probe with its circuit connection where FIG. 12A is a top plan view, FIG. 12B is a sectional view of the probe at rest, and FIG. 12C is a sectional view of the probe when acted upon by force F.

FIGS. 13A and 13B show an embodiment of a compliant probe with an
20 integral ground shield, where FIG. 13A is a top plan view and FIG. 13B is a sectional view.

FIG. 14 shows a sectional view of an alternative embodiment of a compliant probe with an integral ground shield.

FIG. 15A shows a test head apparatus that incorporates compliant probes.

FIG. 15B is a sectional view of the compliant probes in FIG. 15A.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

5 In accordance with the principles of the invention a first preferred embodiment of a compliant probe is shown in FIG. 5. A probe is disclosed that allows reliable electrical connection to be made to contact pads on microelectronic devices such as integrated circuits (ICs), flip-chips, passive devices, and chip scale packages. The probe allows for flexible vertical motion
10 of a probe tip 81 in response to a force on the tip. Thus, as a contact pad is urged into contact with probe tip 81, mechanical compliance of the structure allows the tip to make contact with the mating contact pad at a force sufficient for probe tip 81 to penetrate an insulating oxide film on the contact pad. Mechanical compliance of the probe accommodates differences in height of the
15 contact pads in a region of the microelectronic device, while providing sufficient force on each probe tip to assure a reliable electrical connection between tip 81 and a corresponding contact pad. Further, mechanical compliance of the pad is necessary to allow the tip to maintain a connection to the corresponding pad during a test or burn-in cycle where thermal expansion may cause warping of
20 the device and of the probe support.

In FIG. 5, probe tip 81 is supported on an elongated thin spring of conductive material 83. Thin spring 83 is supported by posts 85 that are joined to contact pads 84 on each end of elongated thin spring 83. Probe tip 81 is able to move flexibly in response to a force applied vertically to tip 81. Vertical
25 movement of tip 81 causes flexible bending and stretching of thin spring 83 such that a compliant restoring force is impressed on tip 81.

In the compliant probe shown in FIG. 5, posts 85 are supported above substrate 89 by terminals 86 which are connected electrically to circuit trace 87. Circuit trace 87 is connected in turn to electrical circuitry in substrate 89 by means of via 88. The series of links described above connect probe tip 81 to
5 circuits in the substrate 89 in order to operate a device connected to the probe. In applications such as burn-in, substrate 89 is made of silicon or a low expansion ceramic material in order to achieve dimensional stability over a wide temperature range, typically from 25 °C to 150 °C.

For operation at high frequencies, the electrical links from probe 81 to via
10 contact 88 are arranged to minimize inductance of the connection to probe tip 81. Inductance of the loop is minimized by locating via contact 88 substantially under probe tip 81. While via 88 cannot always be ideally so located, the distance between tip 81 and via 88 is short for applications that require high frequency operation.

15 FIG. 6 shows a second embodiment of a compliant probe in which an elongated thin spring 93 is shielded from circuitry in a substrate 99 by a ground plane shield 92. Ground plane shield 92 is insulated electrically by dielectric layers 98A and 98B. Dielectric layer 98A is sandwiched between the top surface of substrate 99 and ground plane 92. Optional dielectric layer 98B is an
20 elastomeric dielectric material that is sandwiched between ground plane 92 and thin spring 93. The elastomeric material of layer 98B is preferably selected from the group consisting of silicone, fluorosilicone, fluorocarbon, and urethane polymers. Elastomeric dielectric layer 98B insulates thin spring 93 from ground plane 92 while allowing spring 93 to flex vertically.

25 In FIG. 6, contact pads 94 on each end of elongated thin spring 93 are joined to posts 95, which in turn rest on pads 96 on substrate 99. Electrical connection to a probe tip 91 is made through thin spring 93 to contact pads 94

joined to posts 95 resting on terminals 96 that are connected to electrical circuits in substrate 99 by a circuit trace 97.

As seen in FIG. 6, probe tip 91 is disposed on thin spring 93 at a predetermined position along the centerline between posts 95 at each end of elongated thin spring 93. A vertical force on probe tip 91 causes elastic bending and stretching of thin spring 93, and deformation of elastomeric dielectric layer 98B. A vertical force on probe tip 91 is compliantly opposed by counterforces produced by the elastic bending and stretching of thin spring 93, and by deformation of elastomeric layer 98B.

FIG. 7A shows a plan view from above of a first embodiment of a compliant probe of the general type illustrated in FIG. 5. Elongated thin spring 103 is made of a sheet of metal including contact pads 104 formed in each end of the sheet. The metal of thin spring 103 is chosen to exhibit a high yield strength and a moderate elongation at ultimate failure. Metals such as molybdenum, columbium, stainless steel, beryllium-copper, cupro-nickel, nickel, titanium, and alloys thereof are preferred. One suitable metal is beryllium-copper alloy ASTM Spec. No. B534, with a yield strength of 550 mega-Pascals. Another suitable metal is titanium alloy Ti, 8 Al, 1 Mo, 1 V, with a yield strength of 910 mega-Pascals.

Probe tip 101 shown in FIG. 7A is supported on thin spring 103 such that probe tip 101 will depress vertically toward a substrate 109 in response to a vertical force F applied to the probe tip. A vertical depression of probe tip 101 is shown in the sectional views of FIGS. 7B and 7C. A force F applied to probe tip 101 flexibly bends thin spring 103 allowing tip 101 to depress toward substrate 109. As seen in the sectional view in FIG. 7C, the vertical motion of probe tip 101 is due bending and stretching of strip 103.

Probe tip 101 is a pyramid formed by replication of an etch pit formed in a crystallographic (100) silicon surface by well-known processes. The tip angle of 54.75 ° is determined by the (111) crystallographic planes in silicon that form the faces of the pyramid. The material of tip 101 is tungsten, which forms a sharp, hard point that is able to break through the aluminum oxide layers on aluminum contact pads typically used on semiconductor IC devices. Materials suitable for making hard probe tips include molybdenum, nickel alloys, osmium, Paliney 7, rhodium, rhenium, titanium, tungsten, and alloys thereof.

Fabrication of sharp probe tips by replication of etch pits in silicon is well known in the field and is well described in a 1973 publication by D. A. Kiewit in Reviews of Scientific Instruments, Vol. 44, pages 1741-1742. Kiewit describes fabrication of probe tips that are made by replication of etch pits in silicon by depositing nickel-boron alloy into the pit, and then removing the silicon matrix material. Kiewit formed pyramidal etch pits in silicon (100) surfaces by treatment of the surface with boiling hydrazine hydrate.

Thin spring 103 is supported above substrate 109 by posts 105 that are joined onto terminals 104 at each end of elongated thin spring 103. Post 105 is formed of an electrodeposited metal preferably selected from the group consisting of hard copper, nickel, a cupro-nickel alloy or hard gold. Electrical connection of probe tip 101 to test circuits is made by conduction through spring 103, contacts 104, posts 105, terminals 106, a circuit trace 107 and a via 108. The electrical circuit from via 108 to probe 101 is configured to form a loop that encloses the smallest area possible in order to reduce inductance and thereby allow operation at high frequencies or data rates.

Several alternative configurations of compliant probes are shown in FIGS. 8A - 8D. Certain configurations facilitate probing of contact pads that are closely spaced in linear arrays on integrated circuits. Contact pads on modern

integrated circuits have a center-to-center spacing as small as 60 microns. In order to contact closely spaced probe pads, specially designed probes are nested in specially designed arrays. Designs shown in FIGS. 8A - 8D provide means to contact to closely spaced arrays of contact pads on integrated circuit
5 devices under test.

A compliant probe shown in FIG. 8A allows nesting of the probe in an array of thin elongated springs oriented at an angle to the axis of a linear array of probe tips 111. The configuration includes a spring with probe tip 111 disposed between a short section 113 and a long section 112 of a thin spring.
10 Contact pads 114 and 116 are provided on the ends of short section 113 and long section 112, respectively. The spring is supported by post 115 under the short section 113 and by post 117 under the long section 112. Staggered positioning of posts 115 and 117 allows close spacing of the probes one to another.

15 In FIG. 8B, a compliant probe is shown that includes an elongated thin spring with a short section 123 terminating at contact pad 124, and a long section 122 terminating at contact pad 126. A probe tip 121 is disposed between long section 122 and short section 123. Contact pad 126 is supported by post 127, and contact pad 124 is supported by post 125. By arranging a
20 plurality of probes of FIG. 8B in a line with alternating short sections and long sections, the probes are nested in a closely spaced array suitable for testing integrated circuits with small pad spacing.

In FIG. 8C, a compliant probe is shown that includes an elongated thin spring 133 held between two contact pads 134 and 136. A probe tip 131 is
25 disposed on spring 133 at a point midway between a post 135 and another post 137 joined to contact pads 134 and 136 respectively. Elongated posts 135 and

137, and elongated contact pads 134 and 136 are oriented at an angle that allows the probes to be nested in a closely spaced array as illustrated in FIG. 8C.

A compliant probe in FIG. 8D includes an elongated thin spring with a short section 143 terminated at a contact pad 144, and a long section 142 terminated at a contact pad 146. A probe tip 141 is disposed on the thin spring between long section 142 and short section 143. Oblong posts 145 and 147 support contact pads 144 and 146 respectively, such that the probes can be nested in a closely spaced array. The spring sections 142 and 143 are flexibly bent and stretched when a contact pad on a device is biased against probe tip 141.

Probe tips shown in FIGS. 9A to 9D are configured for specific applications in testing and burn-in of microelectronic devices. These probe tips and others are well known in the integrated circuit industry. Examples presented here are representative of the many types of probe tip that are in use. Methods of fabrication are well known to practitioners in the art of manufacturing electrical contacts.

A probe tip shown in FIG. 9A is preferred for probing aluminum bond pads on integrated circuits, where sharp apex 153 is suited to breaking through oxide layers on aluminum bond pads. A pyramid 152 is formed by replication of an etch pit in a crystallographically oriented (100) silicon surface. Pyramid 152 is supported on a thin spring 151. Apex 153 of pyramid 152 is sharply defined with an included angle of 54.75° between opposite faces of the pyramid. A hard material is used for probe tip 152, where the material is preferably selected from the group consisting of molybdenum, nickel, osmium, Paliney 7, rhodium, rhenium, titanium, tungsten, and alloys thereof. In probing soft contacts, materials such as osmium, rhodium, and tungsten are preferred because they react slowly with solders and other soft materials.

A probe tip shown in FIG. 9B is preferred for contacting noble metal contact pads. A thin disk 157 is supported on a metal post 156 disposed on a surface of thin spring 155. Post 156 is undercut by a chemical etching process to expose edges of disk 157. Thin disk 157 is made of an inert metal preferably
5 selected from the group consisting of gold, Palladium, Platinum, Rhodium, and alloys thereof.

A probe tip shown in FIG. 9C is preferred for contacting solder and other soft materials. A rounded metal tip 161 on a metal post 162 is disposed on a sheet spring 160. Rounded metal tip 161 is shaped by flash laser melting and
10 reflow of a high temperature material into the shape of a spherical section. Materials suitable for rounded metal tip 161 include metals selected from the group consisting of nickel, platinum, rhodium, cupro-nickel alloys, beryllium-copper alloys, and Palladium.

A probe tip shown in FIG. 9D is preferred for contacting small contact
15 pads and for pads that are spaced closely together. A probe tip 167 with a top edge 166 is disposed on the top surface of a thin spring 165. Probe tip 167 is preferably formed by plating the edge of a sacrificial material and then removing the sacrificial material to leave a thin section of metal 167 oriented in the vertical direction.

20 FIG. 10 shows a third embodiment of a compliant probe where an elongated thin spring 172 provides an enhanced flexibility due to a corrugation 173 oriented with a direction that is transverse to the long axis of thin spring 172. One or more corrugations render spring 172 more easily bent and stretched, allowing for more flexibility in response to a vertical force on probe tip 171.
25 Corrugation 173 is formed by replication of an elongated etch pit formed in the (100) crystallographic surface of silicon. Methods of etching elongated pits in silicon surfaces are well known as represented in an article *Fabrication of Novel*

Three-Dimensional Microstructures by the Anisotropic Etching of (100) and (110) Silicon, by Ernest Bassous in IEEE Transactions on Electron Devices, Vol. ED-25, No. 10 (1978) on page 1184. Corrugations are made by depositing metal stripes in a direction transverse to the long axis of the etch pit.

5 In FIG. 10, terminals 174 on each end of elongated thin spring 172 are joined to posts 175 that support the spring at a predetermined distance above a substrate 179. Posts 175 rest on contact pads 176 that are connected to electrical circuitry in substrate 179 by a circuit trace 177 and a via 178.

10 In FIG. 10, a probe tip 171 is disposed on thin spring 172 at a predetermined distance from the posts 175 at each end of elongated thin spring 172. A vertical force on probe tip 171 causes thin spring 172 to bend and to stretch elastically, as enhanced by flexure of corrugation 173. Height of corrugation 173 is determined by controlling its width, so that it does not touch the top of a device under test.

15 FIG. 11 shows a fourth embodiment of a compliant probe where circuitry 187 on the surface of a substrate 189 is protected by an elastomeric encapsulant 188 that is sandwiched between a thin spring 182 and the top surface of substrate 189. Encapsulant 188 protects against corrosion and mechanical damage while allowing thin spring 182 to move compliantly as a
20 probe tip 181 is urged against a mating contact pad on a device under test.

In Embodiment 4, an elongated thin spring 182 has one or more corrugations 183 with an orientation that is transverse to the long axis of thin spring 182. Spring 182 is supported at a predetermined height above substrate 189 by posts 185 joined to terminals 184 on each end of elongated thin spring
25 182. Posts 185 rest on contact pads 186 that are connected to electrical circuitry in substrate 189 by a circuit trace 187 through a via 188.

A detailed view of Embodiment 3 is shown in FIGS. 12A - 12C for a configuration incorporating two corrugations 193. A top plan view in FIG. 12A shows a compliant probe in which a probe tip 191 is disposed on a thin spring 192. Spring 192 is a cupro-nickel thin film of Monel alloy K-500. The thickness of thin spring 192 is between 10 and 75 microns, and more preferably the range
5 from 25 to 50 microns. The width of thin spring 192 is between 20 and 150 microns and more preferably the width is between 30 to 75 microns. The distance between the centroid of a post 195 at a first end 194 of spring 192, and the centroid of a post 195 at a second end 194 of spring 192 is about 200 to
10 1500 microns in length. More preferably, the center to center spacing between the posts is from 250 to 750 microns in length.

The response of probe tip 191 to a vertical force F is illustrated in FIGS. 12B and 12C, showing a sectional view of the probe before and after the application of force F . As seen in FIG. 12C, a force F acting on probe tip 191
15 deflects thin spring 192 downward toward a substrate 199. Spring 192 is bent and stretched elastically, thereby generating a counter force that compliantly opposes further deflection of tip 191 as it is acted upon by force F . Corrugations 193 enhance compliance by increasing the stretching and the bending motions of spring 192. Specifically, corrugations 193 reduce axial tension in spring 193,
20 significantly relieving stresses caused by stretching of spring 192.

Probe tip 191 is connected to electrical circuitry used to operate a device under test. Probe 191 is connected by spring 192 that is supported by posts 195 joined to contact pads 194 at both ends of elongated thin spring 192. Posts 195 rest upon terminals 196 on the surface of substrate 199. In turn, terminals
25 196 are connected to a circuit trace 197 that is joined to electrical circuitry in substrate 199 by a conductive via 198. Optionally, a ground plane may be inserted between the probe tip 191 and the circuitry in substrate 199 in order to shield tip 191 from signals in adjacent circuit traces in substrate 199.

FIGS. 13A and 13B show a compliant probe that provides a low inductance required for high performance testing of integrated circuits. FIG. 13B shows a sectional view of a compliant probe in which a probe tip 201 is disposed on a thin spring 202. A return ground path for signals in spring 202 is provided by a metal layer 212 that is insulated from spring 202 by a dielectric layer 211 sandwiched therebetween.

Both the signal at probe tip 201 and the associated ground return are linked by short electrical paths to their respective circuits in a substrate 209. Probe tip 201 is connected to a supporting post 205 that is joined to a contact pad 204 on spring 202. Post 205 rests on a terminal 206 connected to a circuit trace 207 that is in turn connected to test circuits in substrate 209. The corresponding ground return on electrode 212 is connected to a support post 215. Post 215 rests on a terminal 216 connected to a ground trace 217 that is in turn connected to ground circuits in substrate 209.

FIG. 14 shows an alternative to the compliant probe with a ground return heretofor shown in FIGS. 13A and 13B. The probe in Fig. 14 is mechanically robust because an elongated thin spring 222 with stress relief corrugations 223 is supported directly at both ends by posts 225. A probe tip 221 is connected to test circuitry in a substrate 229 by links through spring 222, contact pads 224, posts 225, and terminals 226 connected to the test circuitry in substrate 229. A ground electrode 235 is insulated from spring 222 by a dielectric film sandwiched therebetween. The ground return path is from a ground electrode 235 through post 236 to a ground terminal 233 on substrate 229.

A ground return 235 is attached to a separate post 236 attached to a ground terminal 233 on substrate 229. Ground return 235 is insulated from spring 222 by a dielectric film 231 sandwiched therebetween.

FIG. 15A shows a test head apparatus that incorporates compliant probes with ground return electrodes. The test head provides a means to test high performance integrated circuit chips. High performance electrical contacts link pads on the chip to drive circuits 259 that are linked to the input/output channels of a high-speed chip tester. Each probe is connected to a channel (S1, S2, S3, S4, ...) of the chip tester by circuit traces 258 ending in terminals 257 on a ceramic substrate 249.

The test head is built on ceramic substrate 249 that provides mechanical and thermal stability. Each compliant probe includes a probe tip 241 disposed on a thin spring 242 supported at a predetermined distance above the surface of substrate 249 by posts 245. Probe tips 241 flexibly move in the vertical direction to accommodate any differences in the height of contact pads on the chip, while maintaining reliable connections to contact pads on the chip.

Mechanical operation of the compliant probe of FIG. 15A can be understood better by reference to the sectional view in FIG. 15B. Probe tip 241 is disposed on thin spring 242 that incorporates corrugations 243 to increase the flexibility of the probe. Contact pads 244 on each end of elongated thin spring 242 are joined to posts 245. Posts 245 rest on terminals 246 on circuit traces 247 that are connected to the respective circuit traces 258 in substrate 249.

The compliant probe shown in FIG. 15B incorporates a ground return 255 on the top side of spring 242. Ground return 255 is insulated from spring 242 by a thin dielectric film 251 sandwiched therebetween. Ground return 255 is connected to a ground terminal 253 by a post 256. This configuration avoids transmission of mechanical stresses in spring 242 to ground circuit 255.

Although several preferred embodiments of the invention have been described, numerous modifications and alternatives thereto would be apparent

to one having ordinary skill in the art without departing from the spirit and scope of the invention.

CLAIM:

1. A probe for making electrical contact to contact pads on a microelectronic device, said probe comprising:

5 (a) an elongated spring of conductive material with a top and a bottom surface and with a first and a second end;

(b) a rigid substrate with a top and a bottom surface;

(c) electrical terminals disposed on said top surface of said rigid substrate;

10 (d) a plurality of conductive posts each of which is connected to the bottom surface of said thin spring and to one of said electrical terminals on the top surface of said substrate, such that said thin spring is supported at a predetermined distance above the top surface of the substrate;

15 (e) an electrically conductive tip with a base that is disposed on the top surface of said thin spring and with a projection above the top surface of said thin spring, whereby a top surface of said conductive tip provides temporary connection to said contact pads on said microelectronic device;

20 (f) wherein said conductive tip is flexibly moveable in a vertical direction.

2. The probe of claim 1 wherein said thin spring is a substantially flat spring with a longest dimension of between 150 to 1,500 micrometers, and with a thickness of between 10 to 75 micrometers in the thinnest portion of said spring.

3. The probe of claim 1 wherein said thin spring is a metal spring that contains one or more corrugations oriented transverse to the longest dimension of said thin spring.

4. The probe of claim 1 wherein said conductive material is selected from
5 the group consisting of beryllium-copper, columbium, copper-nickel, molybdenum, nickel, nickel-titanium, titanium, tungsten, and alloys thereof.

5. The probe of claim 4 wherein said top surface of said conductive tip is made of a hard metal selected from the group consisting of copper-nickel, nickel, osmium, Paliney 7, platinum, rhenium, rhodium, tungsten, and alloys thereof.

10 6. The probe of claim 1 wherein said electrical circuit pattern underlies said thin spring and a circuit connection to said electrical circuit pattern underlies said electrically conductive tip.

7. The probe of claim 1 wherein said probe tip is a pyramid that is a replica of a pit etched into a surface of single crystal silicon.

15 8. The probe of claim 1 wherein said probe tip is an electroplated bump.

9. A probe for electrically connecting to contact pads on a microelectronic device, said probe comprising:

(a) a thin elongated spring of electrically conductive material with a top and a bottom surface, and with a first and a second end;

20 (b) a rigid substrate with a top and a bottom surface;

(c) a plurality of rigid conductive posts where at least one of said posts is connected to the bottom surface of said first end and said second end of said thin spring so that the thin spring is supported at a predetermined distance above the top surface of the substrate;

25

(d) an electrically conductive tip with a base that is disposed on the top surface of said spring projecting above said top surface, whereby the projection is suited to contacting said contact pads;

5 (e) wherein said conductive tip is positioned on said conductive spring at a distance from each of said support posts whereby the tip is moveable in a vertical direction.

10 10. The probe of claim 9 further including an elastomeric material disposed between said bottom surface of said thin elongated spring and said top surface of said substrate.

11. The probe of claim 10 wherein said elastic dielectric material is selected from the group consisting of silicone, fluorosilicone, fluorocarbon, and urethane polymers.

12. A socket for microelectronic devices where said device has a substantially planar surface with an array of contact pads disposed thereon, said
15 socket comprising:

(a) a substrate with a top surface and a bottom surface;

(b) a plurality of compliant probes for making electrical connections to said contact pads, wherein the probes are disposed in an array on the top surface of said substrate;

20 (c) circuit means connected to said flexible probes whereby said microelectronic devices are operated when the flexible probes are connected to said contact pads;

(d) wherein each of said flexible probes comprises a thin elongated spring of conductive material that is supported on a bottom surface by at least one rigid post at a said first end and at a said second end; and
25

(e) wherein each of said flexible probes includes a probe tip that is disposed on a top surface of said thin elongated spring at a predetermined distance from each of the rigid posts such that said probe tip is moveable.

5 13. The socket of claim 12 wherein said substrate is made of silicon material.

14. The socket of claim 13 wherein said microelectronic device is a plurality of integrated circuits arrayed on an undiced silicon wafer.

10 15. The socket of claim 13 wherein said silicon material is a silicon wafer of thickness between 100 micrometers and 500 micrometers.

16. The socket of claim 12 wherein said substrate is made of ceramic material.

15 17. The socket of claim 16 wherein said substrate is a metal-ceramic multilayer structure whereby each probe is connected to a circuit means for testing and burning in said microelectronic devices.

18. The socket of claim 12 wherein a ground shield is disposed under said thin elongated spring.