

TITLE OF THE INVENTION

Test Contact System For Testing Integrated Circuits With Packages Having An Array Of Signal And Power Contacts

BACKGROUND OF THE INVENTION

[0001] FIELD OF THE INVENTION

[0002] The present invention is directed to equipment for testing microcircuits.

[0003] DESCRIPTION OF THE RELATED ART

[0004] The invention pertains to improvements to equipment for testing microcircuits.

[0005] So-called "Kelvin" testing refers to a process where each microcircuit terminal contacts two test contacts. A preliminary part of the test procedure measures the resistance between the two test contacts. If this value is high, one or both of the two test contacts are not making good electrical contact to the microcircuit terminal. If the possibility of high resistance at this interface will affect the accuracy of the actual testing of the microcircuit performance, then the issue can be addressed according to the provisions of the testing protocol.

[0006] One particular type of microcircuit often tested before installation has a package or housing having what is commonly referred to as a ball grid array (BGA) terminal arrangement. Figures 1 and 2 show an example of a BGA package type of microcircuit 10. Such a package may have the form of a flat rectangular block, with typical sizes ranging from 5 mm to 40 mm on a side and 1 mm thick.

[0007] Figure 1 shows microcircuit 10 with a housing 13 enclosing the actual circuitry. Signal and power (S&P) terminals 20 are on one of the two larger, flat surfaces, surface 14, of housing 13. Signal and power (S&P) terminals 20 surround a projection 16 on surface 14. Typically, terminals 20 occupy most of the area between the surface 14 edges and spacer 16 rather than only a portion of the area as is shown in Figure 1. Note that in some cases, spacer 16 may be an encapsulated chip or a ground pad.

[0008] Figure 2 shows an enlarged side or elevation view of terminals 20 as they appear with surface 14 on edge. Each of the terminals 20 includes a small,

approximately spherical solder ball that firmly adheres to a lead from the internal circuitry penetrating surface 14, hence the term "ball grid assembly." Figure 2 shows each terminal 20 and spacer 16 projecting small distances away from surface 14, with the terminals 20 projecting farther from surface 14 than the spacers 16. During assembly, all terminals 20 are simultaneously melted, and adhere to suitably located conductors previously formed on the circuit board.

[0009] Terminals 20 may be quite close to each other. Some have centerline spacings of as little as 0.5 mm, and even relatively widely spaced terminals 20 are still around 1.5 mm apart. Spacing between adjacent terminals 20 is often referred to as "pitch."

[0010] .

BRIEF SUMMARY OF THE INVENTION

[0011] The aspect directed to a test contact system for testing integrated circuits with packages having an array of signal and power contacts and alleviating the problem of debris on the contacts.

[0012] The connection via test receptacle in some applications may have a cup shape with an open end, with the open end of the cup-shaped via contacting the aligned test contact element. Therefore, debris resulting from loading and unloading devices under test from the test equipment can fall through the test contact elements where the cup-shaped vias impound the debris.

[0013] The contact and interface membranes may be used as part of a test receptacle including a load board. The load board has a plurality of connection pads in substantially the predetermined pattern of the test contacts elements. The load board supports the interface membrane with each of the connection pads on the load board substantially aligned with one of the connection vias and in electrical contact therewith.

[0014] The structure of the device may provide a wiping function during testing on the sides of the ball terminals rather than the end that will contact the circuit board, while also providing very good electrical contact. The wiping function usually breaks through any oxide layers present on terminals. Each test contact has a hole in the middle of the contact surface, so the end of the terminal is not marked during testing. This is particularly useful for lead-free terminals which tend to create thicker oxide layers. The vias that connect the test contact elements to the load board can be

modified with springs to allow for microcircuit packages that do not have coplanar terminals and to provide Z axis compliance.

[0015] An embodiment is a test receptacle for making temporary electrical contact with a plurality of microcircuit terminals having a predetermined pattern, comprising: a test contact element array comprising a plurality of test contact elements arranged in substantially the predetermined pattern of the plurality of microcircuit terminals, each test contact element in the plurality comprising a resilient finger projecting from an insulating membrane as a cantilevered beam, and having on a contact side thereof a conducting contact pad for contacting a corresponding microcircuit terminal in the plurality; a plurality of connection vias arranged in substantially the predetermined pattern of the plurality of microcircuit terminals, each connection via in the plurality aligned with one of the test contact elements; an interface membrane supporting the plurality of connection vias. At least one of the connection vias (83-85) is cup-shaped with an open end, with the open end of the cup-shaped via (83-85) contacting a corresponding test contact element (56-58).

[0016] Another embodiment is a test fixture for forming a plurality of temporary mechanical and electrical connections between a device under test having a plurality of terminals and a load board having a plurality of connection pads, the terminals and connection pads being in a one-to-one correspondence, comprising: a replaceable interface membrane disposed generally parallel to and adjacent to the load board, the interface membrane including a plurality of vias in a one-to-one correspondence with the plurality of connection pads of the load board, each via being cup-shaped with a base adjacent to a corresponding connection pad on the load board and a rim extending away from the load board; and a replaceable contact membrane disposed generally parallel to and adjacent to the interface membrane, the interface membrane being between the load board and the contact membrane, the contact membrane including a plurality of connection pads facing the interface membrane, each via on the interface membrane corresponding to at least one connection pad on the contact membrane, the contact membrane including a plurality of contact pads facing away from the interface membrane, each contact pad in the plurality being permanently electrically connected to at least one of the plurality of connection pads, each via on the interface membrane corresponding to at least one contact pad on the contact membrane. Each contact pad corresponding to a particular via is configured to mechanically and electrically receive the terminal on the device under test

corresponding to the particular via. When the device under test is attached to the test fixture, the interface membrane contacts the load board, the contact membrane contacts the interface membrane, and the plurality of terminals on the device under test are electrically connected in a one-to-one correspondence to the plurality of connection pads on the load board.

[0017] A further embodiment is a test fixture for forming a plurality of temporary mechanical and electrical connections between a device under test and a load board, comprising: a membrane for mechanically and electrically contacting the load board; a plurality of vias disposed in the membrane, each via in the plurality being associated with a terminal on the device under test and a contact pad on the load board, each via in the plurality having an electrically conducting wall for conducting current between the terminal and the contact pad; and a plurality of springs disposed within the plurality of vias in a one-to-one correspondence, each spring in the plurality providing a mechanical resisting force to the terminal when the device under test is engaged with the test fixture.

[0018] A still further embodiment is a test fixture for forming a plurality of temporary mechanical and electrical connections between a device under test and a load board, comprising: a membrane for mechanically and electrically contacting the load board; a plurality of vias disposed in the membrane, each via in the plurality being associated with a terminal on the device under test and a contact pad on the load board; a plurality of springs disposed within the plurality of vias in a one-to-one correspondence, each spring in the plurality providing a mechanical resisting force to the terminal when the device under test is engaged with the test fixture; and a pair of open-ended tubes, the open end of one tube fitting within the open end of the other tube, the tubes being longitudinally slidable with respect to each other, the tubes surrounding and housing the spring.

[0019] A still even further embodiment is a test fixture for forming a plurality of temporary mechanical and electrical connections between a device under test and a load board, comprising: a membrane for mechanically and electrically contacting the load board; a plurality of vias disposed in the membrane, each via in the plurality being associated with a terminal on the device under test and a contact pad on the load board; a plurality of springs disposed within the plurality of vias in a one-to-one correspondence, each spring in the plurality providing a mechanical resisting force to the terminal when the device under test is engaged with the test fixture; and an

electrically conducting ribbon for conducting current between the terminal and the contact pad, the ribbon including at least one strand interwoven with the spring and electrically connecting a first longitudinal end of the spring to a second longitudinal end opposite the first longitudinal end.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

- [0020] Figure 1 is a perspective view of a BGA microcircuit showing the terminals array.
- [0021] Figure 2 is an enlarged side elevation view of a BGA microcircuit.
- [0022] Figure 3 is a perspective view of a part of the test equipment having a DUT well for receiving the DUT for testing.
- [0023] Figure 4 is a side elevation cross section of the test equipment of Figure 3.
- [0024] Figure 5 is a substantially enlarged top elevation view of a portion of a test contact array.
- [0025] Figure 6 is a side section view through the test contact array in exploded condition.
- [0026] Figure 7 is a side section view through the test contact array in assembled condition.
- [0027] Figure 8 is a side section view through the test contact array with ball terminals in test position on the test contacts.
- [0028] Figure 9 is a further enlarged top elevation view of a single test contact, and showing additional features of a preferred embodiment.
- [0029] Figure 10 is a perspective view of a test contact array.
- [0030] Figure 11 is a top elevation view of a complete, commercially usable interface membrane including alignment features.
- [0031] Figure 12 is a top elevation view of a complete, commercially usable contact membrane including alignment features.
- [0032] Figure 13 is a top elevation view of a complete, commercially usable spacer membrane including alignment features.
- [0033] Figure 14 is a perspective view of an alternative embodiment of the invention, using a spacer membrane to control device presentation height.
- [0034] Figure 15 is a top elevation view of a test contact showing the position of a spring biasing the test contact fingers.

[0035] Figure 16 is a side view of a test fixture having a single coil spring inside each via, with the device under test not yet engaged with the test fixture.

[0036] Figure 17 is a side view of the test fixture of Figure 16, with the device under test engaged with the test fixture.

[0037] Figure 18 is a plan drawing of a of a 64-position module, which is derived from a 289-position base module.

[0038] Figure 19 is a plan drawing of the full 289-position module.

[0039] Figure 20 is a cutaway drawing of a spring mechanism in an uncompressed state, where a device under test is disengaged from the test fixture.

[0040] Figure 21 is a cutaway drawing of the spring mechanism of Figure 20 in a compressed state, where the device under test is fully engaged with the test fixture.

[0041] Figure 22 is a side-view drawing of a spring mechanism in the uncompressed state.

[0042] Figure 23 is a side-view drawing of the spring mechanism of Figure 22, in the compressed state.

[0043] Figure 24 is a top-view drawing of the spring mechanism of Figures 22 and 23.

[0044] Figure 25 is a side-view drawing of a spring mechanism that uses an enlarged turn of the spring to anchor the spring to a ridge in the via wall.

[0045] Figure 26 is a side-view drawing of a spring mechanism in the uncompressed state, in which a ribbon conductor flexes away from the spring at the top and bottom of the spring mechanism 260.

[0046] Figure 27 is a side-view drawing of a spring mechanism in which the ends of a ribbon conductor extend outwardly from the inside of the top coil of a spring.

[0047] Figure 28 is a side-view drawing of a spring mechanism in which the ends of a ribbon conductor extend inwardly from the outside of the top coil of a spring.

[0048] Figure 29 is a side-view drawing of a leaf spring mechanism.

[0049] Figure 30 is a side-view drawing of a portion of a test fixture that has a textured surface on the contact pad facing the device under test (not shown).

[0050] Figure 31 is a top-view drawing of the contact pad of Figure 30.

[0051] Figure 32 is a top-view drawing of a contact pad having a textured

surface with rectangular features.

[0052] Figure 33 is a top-view drawing of another contact pad having a textured surface with concentric circular features.

[0053] Figure 34 is a side-view drawing of an exemplary test fixture that includes angled contact pads.

[0054] Figure 35 is a side-view drawing of another exemplary test fixture that includes angled contact pads.

[0055] Figure 36 is a side-view drawing of a spring mechanism in the uncompressed state.

[0056] Figure 37 is a side-view drawing of the spring mechanism of Figure 36, in the compressed state.

[0057] Figure 38 is a top-view drawing of the ribbon conductor of Figures 36 and 37.

[0058] Figure 39 is a cutaway drawing of a spring mechanism that uses a pair of nested, open-ended tubes and an elastomeric material.

DETAILED DESCRIPTION OF THE INVENTION

[0059] A test contact element for making temporary electrical contact with a microcircuit terminal comprises at least one resilient finger projecting from an insulating contact membrane as a cantilevered beam. The finger has on a contact side thereof, a conducting contact pad for contacting the microcircuit terminal.

[0060] Preferably the test contact element has a plurality of fingers, which may advantageously have a pie-shaped arrangement. In such an arrangement, each finger is defined at least in part by two radially oriented slots in the membrane that mechanically separate each finger from every other finger of the plurality of fingers forming the test contact element.

[0061] A plurality of the test contact elements can form a test contact element array comprising the test contact elements arranged in a predetermined pattern. A plurality of connection vias are arranged in substantially the predetermined pattern of the test contacts elements, with each of said connection vias is aligned with one of the test contact elements. Preferably, an interface membrane supports the plurality of connection vias in the predetermined pattern. Numerous vias can be embedded into the pie pieces away from the device contact area to increase life. Slats separating fingers could be plated to create an I-beam, thereby preventing fingers from

deforming, and also increasing life.

[0062] The connection vias may have a cup shape with an open end, with the open end of the cup-shaped via contacting the aligned test contact element. Debris resulting from loading and unloading DUTs from the test equipment can fall through the test contact elements where the cup-shaped vias impound the debris.

[0063] The contact and interface membranes may be used as part of a test receptacle including a load board. The load board has a plurality of connection pads in substantially the predetermined pattern of the test contacts elements. The load board supports the interface membrane with each of the connection pads on the load board substantially aligned with one of the connection vias and in electrical contact therewith.

[0064] This device uses a very thin conductive plate with retention properties that adheres to a very thin non-conductive insulator. The metal portion of the device provides multiple contact points or paths between the contacting I/O and the load board. This can be done either with a plated via hole housing or with plated through hole vias, or bumped surfaces, possibly in combination with springs, that has the first surface making contact with the second surface, i.e., the device I/O.

[0065] The device I/O may be physically close to the load board, thus improving electrical performance. In addition the present device also provides compliance thus allowing its use in both manual and automated test equipment.

[0066] The device's structure provides a wiping function during testing on the sides of the ball terminals rather than the end that will contact the circuit board, while also providing very good electrical contact. The wiping function usually breaks through any oxide layers present on terminals 20. Each test contact has a hole in the middle of the contact surface, so the end of the terminal 20 is not marked during testing. A by-product is to self-align device to contact pads on the membrane. This is particularly useful for lead-free terminals which tend to create thicker oxide layers. The vias that connect the test contact elements to the load board can be modified with springs to allow for microcircuit packages that do not have coplanar terminals and to provide additional Z axis compliance.

[0067] The device is compatible with terminals 20 having fine pitch and could be easily used to interconnect to die or wafers. The concept has been successful for terminals with pitch from 1.27 mm down to 0.5 mm. The non-conductive material holds the conductive portion of the design in place and aligns the package, die, and

wafer I/O on any of the alternatives mentioned above.

[0068] Figure 3 shows the general arrangement of a test receptacle 30 for a DUT that includes a BGA type microcircuit 10 of the type shown in Figures 1 and 2. A load board 47 supports an alignment plate 45 having an opening or aperture 33 that precisely defines the X and Y (see the coordinate indicator) positioning of the microcircuit 10 in receptacle 30. If microcircuit 10 has orientation features, it is common practice to include cooperating features in aperture 33.

[0069] Load board 47 carries on its surface, connection pads connected to a cable 42 by S&P conductors. Cable 42 connects to the electronics that perform that electrical testing of microcircuit 10. Cable 42 may be very short or even internal to receptacle 30 if the test electronics are integrated with receptacle 30, or longer if the test electronics are on a separate chassis.

[0070] A test contact array 40 having a number of individual test contact elements precisely mirrors the BGA terminals 20 carried on surface 14 of microcircuit 10. When microcircuit 10 is inserted in aperture 33, terminals 20 precisely align with test contact array 40. Receptacle 30 is designed for compatibility with a test contact array 40 incorporating the device.

[0071] Test contact array 40 is carried on a contact membrane or sheet 50. Membrane 50 initially includes an insulating plastic core layer 61 (see Figure 6) such as Kapton (TM DuPont Corp.) with a layer of conductive copper on each surface. The Kapton layer and the copper layers may each be on the order of 25 microns thick. Individual test contacts in array 40 are preferably formed on and in membrane 50 using well-known photolithographic and laser machining processes.

[0072] Membrane 50 has alignment features such as holes or edge patterns located in the area between alignment plate 45 and load board 47 that provide for precise alignment of membrane 50 with corresponding projecting features on alignment plate 47. All of the test contacts 40 are in precise alignment with the membrane 50 alignment features. In this way, the test contacts of array 40 are placed in precise alignment with aperture 33.

[0073] The section view of Figure 4 shows the general arrangement of test receptacle 30 with membrane 50 on edge, and with the section plane passing through some of the test contacts of array 40. The individual elements are slightly spaced in Figure 4 so as to allow better understanding of the structure. When configured for use, the upper surface of membrane 50 contacts the lower surface of alignment plate

45, with all the elements of receptacle 30 held firmly together by machine screws or other fasteners.

[0074] The lower surface of membrane 50 mechanically contacts an interface membrane 80 of a special design. Membrane 80 has an array 90 of conductor vias. The ends of each via in array 90 extend slightly past the two surfaces of membrane 80 and are in precise alignment with test contacts 40. The term "via" here is used to denote a conductive column or post that extends completely through membrane 80 and is exposed on each side of membrane 80, although in this application the term "pad" is perhaps more descriptive of the actual shape than is "column." The vias that comprise array 90 and other features of membrane 80 are conventionally formed by well-known photolithographic processes.

[0075] The vias comprising via array 90 have two main purposes. First, the vias of array 90 provide mechanical support and clearance space for operation of the array 40 test contacts. The vias of array 90 also electrically connect individual test contacts in array 40 to connection pads 91-93 (see Figures 6 and 7) on load board 47.

[0076] The structure of the test contact elements in array 40 is shown in Figure 5-7. The Figure 5 top projection shows three individual test contact elements 56-58 comprising a small portion of an array 40. Test contacts 56-58 display the detailed structure of all the individual test contact elements in array 40.

[0077] In one application, each of the test contacts 56-58 in array 40 comprise eight tapered fingers 56a, 56b, 57a, 57b, etc. generally configured in a pie shape. The outer ends of each of the fingers 56a, etc. are integral with layer 61 and generally form an arc of the same circle. The fingers 56a, etc. are mechanically and electrically isolated from each other by radially oriented slots 62 and other slots, undesignated. Laser machining is a convenient way to form slots 62. Portions of the initial layers of copper on layer 61 are removed to electrically isolate at least each of the test contacts 40 from each other. For Kelvin testing applications, some fingers 56a, etc. of a single test contact 56 can be electrically isolated from other fingers 56b, etc. as well.

[0078] Individual fingers 56a, etc. each subtend arcs of 45 degrees for an eight-finger embodiment. Other numbers of fingers 56a, such as two, three, four, five, six, and so forth may be alternatively used as well. In fact, rectangular rather than pie-shaped fingers may well be suitable for DUTs that do not have a BGA configuration. To avoid bridges of membrane area between adjacent test contacts 56, etc. that are too thin, individual test contacts 56, etc. are rotated 22.5 degrees with

respect to each neighbor. This orientation spaces the ends of slots 62 in each of the test contacts 56, etc. as far as is possible from the slots 62 within the neighboring test contacts 56, etc.

[0079] Figures 6 and 7 are side elevation sections through the slots 62 etc. that define the lower edges of fingers 56a, 56b, 58a, and 58b of test contacts 56 and 58. Note that the proportions between the dimensions are not drawn to scale. The section cut for Figures 6 and 7 essentially bisects fingers 57a and 57b. One set of fingers 56a, etc. comprises one test contact 56, etc. Each of the fingers 56a, etc. is spaced from all of the other fingers of that test contact 40.

[0080] Each of the fingers 56a, etc. has a contact pad 63a, 63b, etc. facing in the positive Z direction. Pads 63a, 63b, etc. form for test contact 56, the surfaces that contact a terminal 20. Each finger 56a, etc. also has a connection pad 75a, 75b, etc. facing downwardly, in the negative Z direction. Contact pads 63a, 63b, etc. are in respective electrical contact with connection pads 75a, 75b, etc. This electrical connection can comprise plated edges 69a, 69b, 70a, 70b, 71a, 71b of fingers 56a, etc. as shown, or can comprise vias (not shown) that connect pads 63a, etc. to pads 75a, etc. through the inner layer 61 at a convenient point.

[0081] Each of the fingers 56a, etc. forms a cantilever beam that can elastically deflect out of the plane of membrane 50 by flexing layer 61 and, depending on the particular configuration, one or both of pads 63a, etc. and 75a, etc. comprising each of the fingers 56a, etc. To avoid stress concentration at the bases of the fingers 56a, etc., the bases of slots 62 may be wider than other points along slots 62. The bases of slots 62 that are wider may have the form of small circular openings or enlargements 66.

[0082] When in use, fingers 56a, etc. deflect downward, i.e. in the negative Z direction slightly. High stress concentration may result in permanent distortion of fingers 56a, etc. after repeated bending, which enlargements 66 at least partially alleviate. Enlargements 66 can be formed as part of the laser machining process that forms slots 62.

[0083] Interface membrane 80 is interposed between load board 47 and contact membrane 50. Membrane 80 may be somewhat thicker than membrane 50, since very little flexing of membrane 80 is required. The via array 90 in membrane 80 includes individual vias 83-85 having a cylindrical shape. Membrane 80 supports and positions the via array 90 as represented by vias 83-85, and places them in

alignment with respectively, test contacts 56-58.

[0084] Load board 47 has connection pads 91-93 that connect using conventional technology to cable 42. Pads 91-93 are in precise alignment with the associated vias 83-85, thereby making solid electrical and mechanical contact with vias 83-85. This arrangement provides for extremely short conduction lengths between the BGA contacts 20 of a DUT 10 and the load board 47 connection pads 91-93.

[0085] Vias 83-85 have the shape of a cup with open end up, as shown in Figures 6 and 7. The edge of each via 83-85 contacts the adjacent connection pads 75a, etc. on fingers 69a, etc., and similar connection pads on the fingers of test contacts 57, 58, etc.

[0086] A number of reasons exist for this configuration of vias 83-85. In the first place, the structure allows each of the fingers 56a, etc. to flex freely downwards. Secondly, the cup-shaped structure of vias 83-85 is well-suited to collecting most of the inevitable debris that the testing process creates. As fingers 56a, etc. contact individual balls 20, debris that forms, falls through the fingers and is held within the vias 83-85. Protecting load board 47 from this debris prevents electrical performance from degrading and the load board 47 from mechanical damage.

[0087] Figure 7 shows a portion of well when assembled. Connection pads 75a, 75b, etc. are in firm electrical and mechanical connection with via 83. Note that the alignment plate 45 does not restrict flexing of individual fingers 56a, etc. The firm mechanical connection between connection pads 75a, etc. and via 83 minimizes the amount of debris that penetrates the contact area between connection pads 75a, etc. and via 83.

[0088] Figure 8 shows the BGA terminals 20 of a DUT 10 in mechanical and electrical contact with the test contacts 56-58 as contacts 20 might be during an actual test procedure. Fingers 56a, etc. deflect elastically and independently into the interior spaces of vias 83-85 under force applied by a DUT loading element of the test equipment. If an individual BGA terminal 20 is in less than perfect alignment with its test contact 56-58, the independent compliance of each individual finger 56a, etc. assures that good electrical contact occurs between the test contact 56, etc. involved and the associated BGA terminal 20 throughout the test procedure.

[0089] A spacer 100 positions a DUT 10 properly in the Z axis position during loading, and prevents DUT 10 from pressing excessively on test contacts 65, etc.

[0090] The central area of each BGA terminal 20 does not touch any of the fingers 56a, etc. Accordingly, these central areas remain unmarked during the testing procedure.

[0091] The spaces formed by the slots 62 and the gap between the free ends of fingers 56a, etc. allow debris to fall through to the interior of vias 83-85. The cup configuration of each via 83-85 traps the debris and prevents the debris from reaching load board 47 and mechanically damaging load board 47, which is an expensive component of the test equipment.

[0092] Figure 9 is a further enlarged top elevation view of test contact 56, which shows further features thereof. In particular, serrations or teeth 88 on the surfaces 63a, etc. of individual fingers 56a, etc., make contact with BGA terminals 20 during testing. Teeth 88 cut and scratch through any oxide layer on BGA terminals 20 while terminals 20 are pressed onto test contacts 56 etc. Teeth 88 may be positioned at any convenient place on the contact pads 63a, etc. Ideally, teeth 88 are in approximate radial alignment with the circle defining each of the test contacts 56, etc. This allows a cutting effect of teeth 88 on BGA terminal 20 surfaces while microcircuit 10 is loaded into receptacle 30 and BGA terminals 20 deflect fingers 56, etc.

[0093] The teeth 88 can be formed by a variety of techniques. A preferred technique is to form teeth 88 along the edges of fingers 56a as a serendipitous byproduct of the preferred laser machining process for forming slots 62. The use of relatively high laser beam intensity during the slot-forming process causes splashing and furrowing of the copper sheet carried by membrane 50. Ideally, the laser machining beam is directed onto the top surface of membrane 50. Often, the exposed copper surfaces of fingers 56a, etc. are plated with thin layers of nickel and gold. This plating process does not seem to interfere with the ability of teeth 88 to adequately cut into the surfaces of BGA terminals 20.

[0094] The following exemplary values are suitable for various dimensions of the components in a receptacle 30 designed for BGA terminals 20 having 0.8 mm centers. Approximate values for dimensions not specifically stated can be inferred from those given. The diameter of the test contact 56 is 0.5 mm. The width of the slot 62 is 0.03 mm. The thickness of layer 61 is 0.025 mm. The thickness of pads 63a and 75a is 0.018 mm.

[0095] The Z axis compliance of fingers 56a, etc. is a function of finger 56a,

etc. length and thickness and I/O exposure allowing for multiple fields of contacting use.

[0096] Figure 10 is a perspective view of a portion of a contact membrane 50. One can see the individual contact pads 63a, etc. projecting slightly above the surrounding surface of membrane 50.

[0097] Figure 11 is a top elevation view without enlargement, of an interface membrane 80 with a complete via array 90 and alignment features 92 for precisely positioning membrane 80 relative to alignment plate 45.

[0098] Figure 12 is a top elevation view without enlargement, of a contact membrane 50 with a complete test contacts array 40 and alignment features 95 for precisely positioning membrane 50 relative to alignment plate 45. Note the series of holes in each of the four corners of the top contact plate. In each series, there is a large, circular hole, which is a mounting hole. This membrane is mounted to the load board through these holes. Two of the corners have two small, circular holes, while the other two corners have small, elongated holes. These are alignment holes, through which alignment pins pass from the alignment plate, through this membrane and through the remaining pieces of the contactor assembly. The alignment pins hold everything precisely in place.

[0099] The vias 83-85 rigidly contact load board 47, which reduces load board 47 wear, a problem with other test contact designs. The design has a signal path that is relatively short and has only one or two rigid parts, so contact resistance is lower and more consistent than for designs with more parts in the path. This feature also improves electrical performance during the test procedure. The presence of a hollow conductor for a via confines the electric field ("E-fields"). The design reduces the number of right angle connections, improving electrical performance and signal fidelity.

[00100] Figure 13 shows the shape of the interface membrane plate with conductive cups to trap debris and allow fingers from the top contact plate to bend into the via holes.

[00101] Figure 14 shows a spacer to control the depth at which the device is inserted into the contactor, thus controlling the amount of membrane finger flexing. Alignment features 105 position spacer 100 properly in the Z direction with respect to test contact array 40.

[00102] Figure 15 shows vias 83-85 configured with internal springs 110 that

apply force at an intermediate point on fingers 56, etc. Figure 15 shows springs 110 interposed between the bottoms of the interior of vias 83-85 and individual fingers 56-58. The embodiment may in addition to interface membrane 80, require a second interface membrane 80'. The use of a spring 110 has the advantages of additional Z axis compliance, a further conduction path between fingers 56-58 and vias 83-85, and improved overall electrical performance.

[00103] The structure can be modified to allow Kelvin testing on a BGA or Land Grid Array (LGA) device packages. The Kelvin traces, if placed on circuit, could be routed to an interface where they are tied to a Kelvin measuring system without the need to modify boards using a connector to adapt to the Kelvin test system. The test contact 56 structure can be modified to electrically isolate half of the fingers 56a, etc. from the remaining fingers 56a, etc. Individual vias 83-85 can be divided to provide separate connections to the two sets of fingers 56a, etc. comprising each test contact 56, etc.

[00104] A slightly modified pad type can be used as a fiducial for optical handlers that allow very accurate placement of the parts in the test contactor. The tolerances on the extra fiducial pad with a precision cut pattern would allow for optimum centering of the device on the contactor. The pad could be a distance from the device so the housing would need a small hole to allow the optics to align on the pad. Such a modification potentially may eliminate the need for alignment plate 45.

[00105] Alternatively, the design may include electrical isolation between each finger 56, etc. allowing higher thermal capability and reduced inductance of the path by doubling the number of paths from the top side to load board side. Electrically isolating each individual finger 56a, etc. from the other fingers of the test contact 56 may improve electrical performance.

[00106] The pads 63a, etc. can have many different sizes and shapes to match the device and/or device package I/O size, shape and pitch. Different thicknesses and strengths of layer 61; pads 63a, etc.; and 75a, etc. will provide different contact forces to the device I/Os. This feature allows contact force control to best penetrate different types and thicknesses of oxides, both of which range widely. Loaders are limited in the force they can provide. The ability to adjust the contact force allows for matching contact force to loader force.

[00107] A flexible insulating material is used to adjust the device resting point and optimize insertion forces. The spacer 100 thickness will be solely a function of

the ball extension on the device or device package. By making the spacer out of the same material as the contact plate, real time compression adjustment occurs to account for contact pin stress relieving during operations at elevated insertion levels.

[00108] This design uses only two parts to interface both mechanically and electrically between a device and/or device package I/O and a load board during non-destructive device testing. A particular contact membrane 50 is potentially usable for a certain test application or can be a standard footprint for a family of devices with the same pitch. The interface membrane 80 may be a rigid circuit thick and stiff enough to assure the DUT I/O does not make destructive contact with load board 47. In this embodiment, an alignment plate fits on top and aligns the DUT to test contact array 40. Accordingly, multiple devices can be tested at the same time using minimum load board space. The rigid interface membrane 80 has conductor paths that route the signals directly to predetermined test points on the load board. In effect, the interface membrane 80 is specific to the DUT while the test contact array 40 is standardized.

[00109] The test fixture includes two replaceable membranes between the device under test (DUT) 10 and the load board 47. Each of these membranes is relatively inexpensive and easy to replace, compared with a new load board 47, so these membranes are designed to accept damage and debris so that the load board 47 remains undamaged. It should be noted that there may also exist a multitude of mechanical elements for placing and supporting the device under test; these are not discussed here.

[00110] The membranes may be referred to as a contact membrane 50, which faces the device under test 10, and an interface membrane 80, which is between the contact membrane 50 and the load board 47. During the test procedure, the device under test 10 contacts the contact membrane 50, the contact membrane 50 in turn contacts the interface membrane 80, and the interface membrane 80 in turn contacts the load board 47. Each of these membranes 50, 80 includes specific structures, which are detailed below.

[00111] The contact membrane 50 includes a series of paired electrical pads, each pair being on opposite sides of the contact membrane 50, each pair corresponding to a particular pin or terminal 20 on the device under test 10, and the two pads in each pair being permanently electrically connected to each other through the contact membrane 50.

[00112] The pads facing the device under test 10 are referred to as contact pads

56-58, and the pads facing away from the device under test are referred to as connection pads 75. During use, each terminal 20 on the device under test 10 contacts a corresponding contact pad 56-58, making a mechanical and electrical connection between the terminal 20 and the contact pad 56-58. Because the contact pads 56-58 and connection pads 75 are permanently electrically connected, pairwise, there is therefore an electrical connection between each terminal 20 and its corresponding connection pad 75.

[00113] The interface membrane 80 includes a series of vias 83-85, which are essentially cup-shaped holes made out of a conducting material. The base of each cup contacts a button contact membrane which in turn contacts a corresponding connection pad 91-93 on the load board 47. The rim of each cup is spaced apart from the contact membrane 50 when the device under test 10 is detached, and contacts a corresponding connection pad 75 on the contact membrane 50 when the device under test 10 is attached.

[00114] Each via 83-85 on the interface membrane 80 generally has a one-to-one correspondence with a terminal 20 on the device under test 10, and a one-to-one correspondence with a connection pad 91-93 on the load board 47. Note that on the contact membrane 50, there may be a single pad pair for each terminal 20 on the device under test 10, or there may be multiple pad pairs for each terminal 20. Furthermore, the contact pads 56-58 and connection pads 75 may have a one-to-one correspondence, or there may be several contact pads 56-58 for each connection pad 75, or there may be several connection pads 75 for each contact pad 56-58, or there may be a combination of all of these. Although much the language used below assumes a one-to-one correspondence among these pads, it will be understood that there may be several pads on one side of the contact membrane 50 corresponding to each pad on the opposite side of the contact membrane 50, and/or several pads on the contact membrane 50 corresponding to each terminal 20 on the device under test 10. Note that in some applications, it may be desirable to have segregated pads on the contact membrane, which may perform different monitoring tasks – these segregated pads may each have an independent electrical path from one terminal to one of various contacts on the load board.

[00115] We summarize the electrical path during testing: When the device under test 10 is attached to the test fixture, each terminal 20 on the device under test 10 contacts a contact pad 56-58 on the contact membrane 50. Each contact pad 56-58

is permanently electrically connected to a connection pad 75 on the opposite side of the contact membrane 50. Each connection pad 75 on the contact membrane contacts a rim of a via 83-85 on the interface membrane 80 when the device under test 10 is attached to the test fixture. Each via 83-85 on the interface membrane 80 contacts a connection pad 91-93 on the load board 47. In this manner, a circuit is completed between the terminal 20 on the device under test 10 and the connection pad 91-93 of the load board 47. Presumably, the contact resistance along this circuit is sufficiently low, or at least is manageable, in the range of the test frequencies, and the characteristic impedance of the system matches that of the device under test and the test equipment used to measure signals on the device under test. Most systems use a characteristic impedance of 50 ohms.

[00116] There are variations possible to the scheme described in the previous paragraphs. In particular, there are variations to the mechanism used to provide a resisting force to the terminal 20 on the device under test 10. This resisting force provides a general compliance to the test fixture, so that when the device under test 10 is brought into contact with the test fixture, each terminal 20 experiences a small, non-damaging resistance from the contact pad 56-58, generally perpendicular to the plane of the device under test 10. This resisting force ensures a good electrical contact between the terminal 20 and the contact pad 56-58.

[00117] In general, it is desirable that test fixture has a relatively large Z-displacement between when the terminal 20 first contacts the contact pad 56-58 and when the terminal finally comes to rest (i.e., when the device under test 10 is fully engaged in the test fixture). This large Z-displacement may help the test fixture accommodate parts that have relatively loose terminal tolerances. If some terminals on a particular part are longer or shorter than others, the relatively large Z-displacement may help ensure that good electrical contact is made with each terminal, without significant damage to the terminals or to the test fixture.

[00118] In the following paragraph, we summarize one resisting force mechanism, which is described earlier in this document in more detail. Following this summary, we then describe in detail various alternatives to the summarized resisting force mechanism.

[00119] In very basic terms, a terminal 20 on the device under test 10 contacts a portion of the contact membrane 50. The portion of the contact membrane 50, being supported at one end and being free at the other end, deflects in a cantilever-like

fashion. Near the fixed end of the cantilever, the deflected contact membrane 50 contacts a rim of the via 83-85 on the interface membrane 80. The base of the via 83-85 in turn contacts the load board 47. In some applications, the interface between the base of the via 83-85 and the load board 47 is rigid, or non-compliant, because there is sufficient compliance from the cantilever structure. In some applications, the cantilever-like structures on the contact membrane are wedge-shaped, are arranged in a pie shape, are supported at their circumference, and are free in the center of the pie.

[00120] There are alternatives to the pie-shaped cantilever structure for providing a resisting force to the terminals 20 on the device under test 10. Four of these possible alternatives are described sequentially in detail below; it is understood that other alternatives are possible as well.

[00121] A first alternative to the pie-shaped cantilever may be referred to informally as a “single coil spring inside the via”.

[00122] Figures 16 and 17 show a portion of an exemplary test fixture 120 having a single coil spring inside each via. In Figure 16, the device under test 130 is not yet engaged with the test fixture, and is barely contacting the contact pads 141. In Figure 17, the device under test 130 is fully engaged with the test fixture.

[00123] The device under test 130 includes many terminals 131, each of which may be tested independently and simultaneously by the test fixture 120. In many cases, the shape of the terminal 131 may be roughly spherical, and the terminal 131 may be referred to as a ball.

[00124] Each terminal 131 contacts one or more contact pads 141 on the top side of a contact membrane 140. The contact pad 141 may be similar in construction to the contact pads 56-58 described above. In some cases, the shape of the contact pad 141 may be roughly circular, corresponding to the shape of the corresponding terminal 131. In some cases, there is only one contact pad 141 per terminal 131. In other cases, there may be several contact pads 141 for each terminal 131, with the contact pads 141 being segmented. The segmentation may be pie or wedge-shaped, circular, linear in stripes, rectangular, irregular or any other suitable shape. In some cases, the feature length is parallel to the ball movement during insertion into 120.

[00125] The contact pad 141 may optionally include one or more features that protrude out of the plane of the contact membrane 140, such as bumps, edges, hills, and so forth. The optional protruding features may help establish a good electrical connection with the corresponding terminal, and in some cases may allow the test

fixture to work with devices under test 130 that have relaxed tolerances on their respective terminals. In some cases, the optional protruding features have edges corresponding to segmentation edges on the contact pad. In some cases, the optional protruding features may have shapes such as hemispheres, partial spheres, bumps, rectangles, a checkerboard pattern, concentric circles, stripes, or any other suitable shape.

[00126] The contact pad 141 on the top surface of the contact membrane 140 is permanently electrically connected to one or more connection pads 142 on the bottom surface of the contact membrane 140. Such a permanent electrical connection 143 may be may through the contact membrane. The connection pads 142 may also be optionally segmented, but the segmentation may or may not be the same as that of the contact pads 141. In general, each contact pad 141 is associated with a particular terminal, and each connection pad 142 is associated with a terminal; the precise association between a particular contact pad 141 and a particular connection pad 142 is less important than the associations between the pads 141 and 142 and their respective terminals.

[00127] In some cases, the top and bottom surfaces of the top contact plate, or contact membrane 140, are made from the same material and are the same thickness. This may put the metal contact area on or close to a neutral contact area, which may reduce stresses and result in a longer part life.

[00128] When the device under test 130 is attached to the test fixture, the terminals 131 contact their respective contact pads 141 on the contact membrane 140 and force the contact membrane 140 into contact with an interface membrane 150.

[00129] Adjacent to and parallel to the contact membrane 140 is an interface membrane 150, which includes a via 151. The via 151 may be cup-shaped, as described above for the vias 83-85, with a rim facing the contact membrane 140 and a base facing away from the contact membrane 140.

[00130] In some cases, the rim of the via 151 extends beyond the plane of the interface membrane 150, toward the contact membrane 140. In other cases, the rim of the via 151 is flush with the top surface of the interface membrane 150. In some applications, the via 151 has an electrically conducting wall. The rim of the via 151 may be generally circular in cross-section shape, although any suitable shape may be used. In general, it is preferable to avoid sharp angles through any current-conducting portions of the test fixtures, in order to reduce any undesirable impedance and/or

inductance effects.

[00131] The base of the via 151 may be generally circular in cross-section, although any suitable shape may be used. The base may be continuous, or may optionally be segmented. As with the pads mentioned above, the segmentation may take on any suitable shape, and each segment is ultimately associated with a particular terminal 131 on the device under test 130. In some cases, the base of the via 151 may include one or more holes. For sufficiently large holes, the via 151 may be able to vent debris that may have otherwise accumulated inside the via 151.

[00132] The via 151 itself houses a spring 152, which may include one or more coils inside the via. In some cases, the spring 152 is anchored at its base to the interface membrane 150, with its free end facing the contact membrane 140. The spring 152 provides a resisting force, through the contact membrane 140, to the respective terminal 131 on the device under test 130. In general, the spring 152 in each slot provides a bias downward to make sure the lower contact plate, or interface membrane 150, has a good connection to load board 160.

[00133] The spring 152 itself may be an elastically formable coil which, in its relaxed position, extends beyond the plane of the interface membrane 150 toward the contact membrane 140. The base of the coil may be attached to the wall of the via 151 or the base of the via 151. The base of the coil may include one or more loops that lie parallel to the base of the via 151, rather than at a slight incline like most of the loops in the coil. Such coil or coils at the base may optionally be slightly enlarged, and/or may extend into the wall of the via 151 in order to become anchored to the via 151. Similarly, the top of the coil may also include one or more loops that lie parallel to the contact membrane 140, to ensure good contact between adjacent elements without generating any undesirable torques.

[00134] The spring 152 may be made from a metal, and may conduct electricity. As a result, the spring may optionally carry current to and/or from the terminal 131 of the device under test 130 from and/or to the corresponding connection pad 161 of the load board 160. Current may also be carried through the via 151 wall. In general, the wall of the via 151 may be able to conduct more current than the spring, so it is preferable to use the via wall, with or without the spring, for conduction, rather than force all the current through the spring.

[00135] The bottom-most surface of the interface membrane 150 is a bottom contact plate 159. For the purposes of this application, the bottom contact plate 159 is

considered to be part of the interface membrane, although in practice, it may be a separate element. In some cases, the bottom contact plate 159 may be constructed similarly to the contact membrane 140.

[00136] The load board 160 includes various connection pads 161, with each connection pad 161 corresponding to a terminal 131 on the device under test 130. Typically, there is a one-to-one correspondence between the terminals 131 and the connection pads on the load board 160, although other arrangements are possible. The construction of the load board 160 and connection pads 161 are similar to the load board 47 and connection pads 91-93 described above.

[00137] In some cases, the interface membrane 150 may include one or more relatively soft, conductive pads on the side facing the load board 160, so that when the interface membrane 150 and the load board 160 are brought together, the soft pads may deform slightly and help prevent damage to the load board 160. Such soft, conductive pads may be made from gold, or from any other relatively soft, conductive metal. In the absence of these soft, conductive pads, the base of the via 151 may contact an optional conductive pad on the bottom surface of the interface membrane 150 or may directly contact the connection pad 161 on the load board 160.

[00138] With regard to the structure of the interface membrane 150, the structural material 153 that makes up most of the membrane volume may be referred to as an interface plate translator (IPT). The curved radius at the top portion of the IPT may be used to bend the top contact around and relieve the stresses. The top contact plate may be adhered to the IPT through a thin film of solder on both sides. Other methods of adhering the top contact plate to IPT may include using welding, non-conductive epoxy between pie pieces, or conductive epoxy on pie piece pads. The spring in slot or via may provide an upward bias to the top contact plate. This upward bias may allow the fingers to hit balls higher on the sides to keep away from scrubbing on the no contact zone on the bottom of the ball so device under test can be reliably soldered to substrate after testing. The bottom contact plate can be the same as the top contact plate for economic reasons or it can be different. The bottom footprint may optionally match the load board footprint for other on-center technologies to allow for this concept to be a direct replacement for previous concepts that may have inferior performance. The IPT can also have a slight chamfer on bottom to hold the spring in place if the spring is designed with a slightly larger radius on its bottom turn. The top bumps, which may help provide more compliance and

provide scrubbing action on side of balls, may be formed using a wire bonder set up to provide formed bump or a standard stud bumping machine. To add height to the flexible contact plate, multiple bump studs may be placed on top of each other to increase the bump height up to 4 mils or more. Depending on equipment forming the stud bumps, the bumps may be formed to either improve scrubbing action on devices that need more wipe due to oxide buildup or to add more height to add more Z-compliance, or a combination of the two.

[00139] The assembly may be set up in an array form similar to the devices being tested. An array may be made with a standard amount of I/O, then the unused locations may either be etched or drilled off to match the I/O locations of the device being tested. For example, Figure 18 is a plan drawing of a 64-position module 181, which is derived from a 289-position base module. Figure 19 is a plan drawing of the full 289-position module 182.

[00140] The model that interfaces with the device under test is in a relatively small physical package and operates like as insert so it can fit into numerous housings including ones that are only slightly bigger than the assembly described above. By having the main interfacing mechanism to the device be an insert, it allows for rapid replacement of modules. Modules needing maintenance can be switched out in minutes, resulting in a decrease in tester downtime. Similar alignment holes in top and bottom contact plate and IPT may simplify replacement, as well.

[00141] A second alternative to the pie-shaped cantilever may be referred to informally as a “single coil spring inside two concentric tubes inside the via”.

[00142] Figure 20 is a cutaway drawing of a spring mechanism 200A in an uncompressed state, where a device under test is disengaged from the test fixture. Figure 21 is a cutaway drawing of the same spring mechanism 200B in a compressed state, where the device under test is fully engaged with the test fixture.

[00143] In both cases, the device under test and terminal, the contact pad that contacts the terminal, and the load board and its connection pad are all similar in construction and function to those shown above.

[00144] Figures 20 and 21 shows a coil spring 201 inside two concentric tubes 202 and 203. The tubes 202 and 203 are both open-ended, with the open end of one fitting within the open end of the other. The tubes 202 and 203 can slide longitudinally with respect to each other, thereby changing the end-to-end length of the spring mechanism 200A, 200B. The spring mechanism is shown with a single

coil spring 201, although more than one coil spring may be placed inside the tubes 202 and 203.

[00145] A potential advantage of placing the spring 201 inside the tubes 202 and 203 is that the wear that arises from repeated compressions and expansions of the spring may be confined to the overlapping portions of the tubes 202 and 203. Such a scheme may reduce wear or accidental contact of the spring with the inner wall of the via. A second potential advantage is that the tubes may reduce or eliminate any torques on the pads that might be formed at either end of the spring. A third potential advantage is that the tubes may be made from a conducting metal, and may assist the via wall in directing current to/from the terminal from/to the load board.

[00146] A potential disadvantage, if the tubes are electrically conductive, is that the resistance and/or inductance of the tubes may change, depending on how much the spring is compressed. For a particularly long terminal on the device under test, there may be a lot of spring compressed when the device under test is fully engaged with the test fixture. For a particularly short terminal, there may be less spring compression. This would lead to test results that vary with the terminal length and with the other tolerances in the device under test, which is also undesirable. In these cases, current may still be adequately carried by the via wall, which does not lead to tolerance-dependent results. In some cases, the pair of tubes may be electrical insulators.

[00147] In Figures 20 and 21, the tube 202 facing the device under test has a larger diameter than that of the tube 203 facing the load board. Alternatively, the tube 202 facing the device under test may have a smaller diameter than that of the tube 203 facing the load board.

[00148] In some applications, the spring mechanism 200A, 200B may be similar in design and in function to a toilet paper holder or paper towel holder, which confines a coil spring to a particular longitudinal axis and allows the spring to be compressed and/or expanded along that axis. It will be understood that in the test fixture, the pair of tubes does not necessarily hold any other elements in place, such as a roll of paper towels. Instead, the pair of tubes provides a housing for the coil spring, which may simplify the mechanical requirements of the interfaces at the longitudinal ends of the spring, and may desirably confine wear to the interface between the overlapping tubes, rather than the inside of the via.

[00149] A third alternative to the pie-shaped cantilever may be referred to

informally as a “single coil spring with a conducting ribbon inside the via”.

[00150] Figure 22 is a side-view drawing of a spring mechanism 220A in the uncompressed state. Figure 23 is a side-view drawing of the spring mechanism 220B of Figure 22 in the compressed state. Figure 24 is a top-view drawing of the spring mechanism 220 of Figures 22 and 23, in either the compressed or uncompressed states.

[00151] The spring mechanism 220 includes a coil spring 221, which provides the mechanical properties of the spring mechanism, as well as a ribbon conductor 222, which provides an electrically conductive path from the top to the bottom of the spring mechanism 220. The flexible ribbon is allowed to bend inside the spring, keeping the same electrical path length the device terminal and the load board pad.

[00152] The ribbon conductor 222 is outside the coil spring 221 at the top and bottom of the coil spring, is woven through spaces the coil spring 221 near the top and bottom ends, and remains inside the coil spring 221 for the remaining length of the coil spring 221.

[00153] As the coil spring 221 flexes and changes length, the ribbon conductor 222 bows inward, near the center of the coil spring 221. Note that the ribbon conductor 222 remains the same length, regardless of the amount of spring compression. In turn, the electrical properties of the ribbon conductor 222, such as resistance and inductance, which depend on the electrical path length through the ribbon conductor 222, are independent of the amount of spring compression. This is a potential advantage of using the ribbon conductor 222 in the spring mechanism 220.

[00154] Note that Figures 22 and 23 show only one cross-sectional view of the spring mechanism 220A and 220B. In practice, the spring mechanism is three dimensional. As a result, the ribbon conductor 222 may not be a single strip, but may be shaped like all or a portion of a waffle ball, with many strips that run top-to-bottom along the spring, with the strips being joined at the top and/or the bottom of the spring. The strips may vary in width along their length, or may have continuous widths along their length.

[00155] The ribbon conductor 222 may be formed with a conductive surface 225 on its outer face and an insulating surface on its inner face 226, which may help reduce or prevent short circuits when the spring 221 is compressed. Alternatively, the locations of the conductive and insulating surfaces may be switched, so that the insulating surface appears on the outward-facing surface and the conducting surface

appears on the inward-facing surface. For this switched orientation, there is typically an additional insulating surface placed over the conductive surface, also facing inward, so that the inner surfaces of the ribbon do not short out if they touch each other when the spring is compressed. This forms a sandwich-like structure for the ribbon, with a pair of insulating surfaces surrounding a conducting surface.

[00156] The ribbon conductor 222 connects electrically to a contact pad 223 on its top surface, which contacts the terminal of the device under test during use. The contact pad 223 may optionally include one or more bumps 224 that may enhance electrical contact and may desirably help scrape off any oxide layers on the terminal that would otherwise inhibit a good electrical connection. The ribbon conductor 222 also connects electrically to a contact pad 227 on its bottom surface, which contacts a connection pad on the load board during use.

[00157] The spring mechanism 220 may be constructed as follows. The ribbon conductor, or flexible circuit on membrane, may be first soldered, epoxy (glued) , or welded to the spring, then wrapped inside spring at or near the bottom spring turn. During use, as the spring compresses to get the needed Z-compliance the circuit on the flexible membrane would bow to take up space inside the spring, but not change its length, thereby keeping the same length electrical path. There may be two, four, six, eight, or any other suitable number of electrical paths routed from the top side of the membrane on the top of spring to the bottom load board interface side.

[00158] Figure 25 is a side-view drawing of a spring mechanism 250 that uses an enlarged turn 253 of the spring 251 to anchor the spring 251 to a ridge 252 in the via wall.

[00159] In some cases, the enlarged turn 253 and ridge 252 are at or close to the top of the spring. In other cases, they are at or near the bottom of the spring 251. In still other cases, they are near the center of the spring 251. In yet other cases, they are away from the top, middle and bottom of the spring 251.

[00160] In some cases, the ridge 252 is formed by first forming the via with a ridge, then hollowing out a portion of the via wall to form the ridge. In other cases, the via wall may be formed in layers, the layers being parallel to the load board. In this layered construction, the ridge may be formed between two layers, or may be its own dedicated layers or dedicated layers.

[00161] Note that contact pad 227 can optionally be separated into two separate pads, creating isolated, separate paths from the contact pad 227 to the load board

interface, which demonstrates a Kelvin connection. Element 257 is a non-conductive portion of the substrate material which separates the pads. The substrate may be made from a thin film of polyimide, commercially available from Dupont, such as ½-mil copper-plated Kapton, which is then plated with a nickel barrier and a gold coating to prevent oxidation and enhance electrical contact.

[00162] Figure 26 is a side-view drawing of a spring mechanism 260 in the uncompressed state, in which a ribbon conductor 222 flexes away from the spring 221 at the top and bottom of the spring mechanism 260. On the top side, facing the device under test, a contact pad 263 and bump 264 flex away from the spring mechanism 260, toward the device under test. On the bottom side, facing the load board, the ribbon conductor 222 flexes away from the spring mechanism 260 at the contact pad 267. Note that the ribbon conductor 222 may bend around the spring 221 to add compliance to the load board interface.

[00163] In the compressed state, the spring mechanism 260 closely resembles the mechanisms 220B and 220 shown in Figures 23 and 24.

[00164] A potential advantage for the flexing longitudinal ends of the spring mechanism 260 is that the flexing creates even more compliance for the test fixture. The bottom portion can flex downward to still make contact even if load board is non-coplanar or warped, even though there may be no stiffeners underneath the board. In some cases, the springs 221 may fit inside a housing with holes or even an IPT, as described above.

[00165] Some other potential advantages to the springs and/or bumps are as follows. Thin copper-plated film in between two thin non-conductive materials may be used in the bend area to relieve stress. Chamfered and radiused holes may help form the contact plate bend and prevent material from yielding, thus increasing contact life. Spring in via hole can add extra path between top contact area and device interface and lower contact plate interfacing to load board. The spring can also just provide mechanical support and bias to both top and bottom contact plates. Bumps on top contact plate can be formed to different shapes by using standard wire bonding equipment and attachment techniques. Multiple wire bonds or stud bumps can be placed on top of each other to make the bump size higher and change area bumps scrub balls on device and at what height bumps first make contact with the device. These bumps can be placed strategically to create a wipe function on the device balls to break through the oxide layer and can be up to four mils high to

improve concept operating range for BGA devices and possible LGA devices as well.

[00166] Figure 27 is a side-view drawing of a spring mechanism 270 in which the ends 273 of a ribbon conductor 272, with bumps 274, extend outwardly from the inside of the top coil of a spring 271. The flexible fingers can be made more rigid with excessive plating. A funnel shape can help align the device to the contact array. Note that the flexible fingers can be bent outward to help align the terminals to the centers of the contacting mechanism. Note also that the configuration in Figure 27 may be especially useful for testing devices that have ball terminals, such as BGAs.

[00167] Figure 28 is a side-view drawing of a spring mechanism 280 in which the ends 283 of a ribbon conductor 282, with bumps 284, extend inwardly from the outside of the top coil of a spring 281. This arrangement may help test devices having flat surfaces, such as pad or leaded devices. Note that the fingers flexing inward allows the fingers to perform a wiping action on the terminal, which can help remove any oxides from the terminal. Note also that the configuration in Figure 28 may be especially useful for testing devices that have pads or leads, such as QFNs, MLFs and SLPs. Note finally that the inward-facing finger concept may be used as single pins, without necessarily having a full top and bottom contact membranes. This is also true for the configurations of Figures 25-27 and 36-38 as well, which may also use single pins rather than top and/or bottom contact plates.

[00168] Before proceeding to the fourth alternative to the pie-shaped cantilever, it is instructive to consider one final alternative spring mechanism 390 that uses the pair of open-ended tubes 392 and 393, but replaces the coil spring with an elastomeric material 391. Such a spring mechanism is shown in Figure 39. An example of an elastomeric material, or elastic polymer, can be rubber, although any suitable elastomer may be used. For the purposes of this application, an elastomeric material is considered to be a spring element.

[00169] Note that the pair of tubes 392 and 393 confines the elastomer to reside inside the pair of tubes. There is some additional air space inside the tubes, which can allow for expansion of the material 391 during compression to keep forces manageable and allow for additional Z-compliance.

[00170] A fourth alternative to the pie-shaped cantilever may be referred to informally as a “leaf spring with a conducting ribbon inside the via”.

[00171] Figure 29 is a side-view drawing of a leaf spring mechanism 290. A ball or terminal 292 on the device under test contacts the contact pad 293 and/or

optional textures 294 on the contact pad. The textures may have a wiping mechanism for pad or leaded application, and may help break through any oxides to improve the electrical connection.

[00172] The contact pad 293 is disposed on the end of a leaf spring 291, which resides inside a via in the membrane 295. Opposite the device under test, the membrane contacts a contact pad 296 on the load board 297.

[00173] The leaf spring includes an optional self alignment mechanism, in which the contact pad 293 includes a local tilt away from being parallel to the load board. This local tilt forces the terminal 292 into more secure contact with adjacent pads 293.

[00174] Element 299 may be a bottom contact plate, which may help prevent debris from reaching the load board 297.

[00175] In Figure 29, the leaf spring 291 is shown in the compressed state. When the spring is uncompressed, the arms with the contact pads 293 and bumps 294 open outward, similar to the pads in Figures 16 and 26, described above.

[00176] Alternatively, the leaf spring arms may extend radially outward, from the center of the via, rather than extending radially inward, as shown in Figure 29.

[00177] In some cases, the leaf spring may be made from a conductive metal, and may conduct current to/from the terminal from/to the load board. In some cases, the leaf spring may be the sole current carrier through the via. In other cases, the leaf spring may conduct, along with the wall of the via. In still other cases, the wall of the via may be the sole electrical conductor through the via.

[00178] The following section describes various surface patterns that may be used on the contact pad closest to the terminal on the device under test. Any or all of these surface patterns may desirably help scrape away any oxide that may have formed on the terminal, and may therefore improve electrical contact between the device under test and the test fixture. Any or all of these surface patterns may be used with any or all of the spring mechanisms, contact pad configurations and bump configurations described above.

[00179] Figure 30 is a side-view drawing of a portion of a test fixture 300 that has a textured surface 302 on the contact pad 301 facing the device under test (not shown). The textured contact pad 301 is formed on the top surface of a membrane 303. A corresponding contact pad 304 is formed on the bottom surface of the membrane 303, which may contact a corresponding contact pad on a second

membrane or on the load board. The top and bottom contact pads 301 and 304 are in permanent electrical connection with each other, and may be electrically connected at one or more locations through the membrane 303.

[00180] Figure 31 is a top-view drawing of the contact pad 301 of Figure 30. The contact pad 301 has a series of stripes or ridges 302. In some cases, the ridges 302 have angled sides and/or sharp angled corners, which may improve electrical contact with the device under test.

[00181] The ridges 302 may be formed by such methods as lasering a portion of the way into the metal pad, by selectively etching down into the pad, or by any other suitable method.

[00182] Figure 32 is a top-view drawing of another contact pad 321 having a textured surface with rectangular features 322. In some cases, the rectangles may be raised or lowered out of the plane of the contact pad 321. In other cases, the rectangles may have a pyramid-like shape, with portions that are non-parallel to the plane of the contact pad.

[00183] Figure 33 is a top-view drawing of another contact pad 331 having a textured surface with concentric circular features 332. As with the rectangular design, one or more of the concentric circles may be raised or lowered out of the plane of the contact pad 331.

[00184] The three textured designs shown in Figures 30-33 are merely exemplary. In practice, any design that provides an angled surface and/or sharp angles on the surface that contacts a terminal on the device under test may be used.

[00185] In addition, any or all of the textured designs may be used on any of the contact pads shown above, including pads that include bumps, and the pads on the ends of the conductive ribbon.

[00186] As an alternative to providing portions of the contact pad that are angled, where the plane of the contact pad is generally parallel to the load board, it is possible to angle the entire contact pad. This provides a surface to have device balls rub against during insertion into the contactor.

[00187] For instance, Figure 34 is a side-view drawing of an exemplary test fixture 340 that includes angled contact pads 342. The test fixture includes a membrane 341 that deflects under the effects of spring 344. The ends of the springs 344 are deliberately angled at the contact pads 343, rather than being flat, as shown in earlier drawings, such as Figures 20 and 21.

[00188] Another angled-pad design is shown in Figure 35. In this exemplary test fixture 350, the membrane 351 bends or deforms slightly in the region of each via 354. Each via 354 is angled slightly, so that one side 355 extends farther toward the device under test than the opposite side 356. In practice, the via 354 may have a flat, but angled, interface at the bottom contact pad 353, which is shown only in cross-section in Figure 35. As a result of this angled interface with the via 354, the contact pad 352, which contacts the terminal on the device under test (not shown) is also angled. In other cases, it is possible to form the angle by increasing the thickness on one side of the contact pad on the membrane, rather than on the via. Other combinations are possible as well.

[00189] Such an angled-pad design may be manufactured by removing material from one side of the via, such as by lasering or etching material away, and/or by adding material to the other side of the via using a plating process.

[00190] There may be one or more advantages to having an angled contact pad, as shown in the examples of Figures 34 and 35. For instance, when the terminal contacts the angled pad, there may be a sliding or scraping action, caused by “sliding down a slope” along the contact pad, which may help break through and/or scrape away any oxides that have built up on the terminal. This, in turn, improves electrical contact at the terminal. In addition, this self-cleaning wiping action may help push the scrape-away oxides from the contact surface, thereby increasing the mean time between cleanings of the top contact plate.

[00191] Finally, we describe one more alternative for the ribbon conductor, first shown in Figures 22-28. Figure 36 is a side-view drawing of a spring mechanism 360A in the uncompressed state. Figure 37 is a side-view drawing of the spring mechanism 360B of Figure 36, in the compressed state. Figure 38 is a top-view drawing of the ribbon conductor 360 of Figures 36 and 37.

[00192] The spring mechanism 360A and 360B includes a coil spring 361, which provides the mechanical properties of the spring mechanism, as well as a ribbon conductor 362, which provides an electrically conductive path from the top to the bottom of the spring mechanism 360A and 360B.

[00193] The ribbon conductor 362 is outside the coil spring 361 at the bottom of the coil spring (adjacent to the load board), is woven through spaces the coil spring 361 near the bottom ends, and remains inside the coil spring 361 for the remaining length of the coil spring 361. The contact pads 363 may emerge outward through the

top coil in the spring 361, as shown in Figures 36 and 27, or may alternatively emerge inward around the top coil of the spring, as in Figure 28.

[00194] In general, the configuration of the top contact pads, adjacent to the device under test, depends on what kind of device is being tested, such as BGA devices with balls, or QFN or SOP devices with pads or flat leads.

[00195] The ribbon conductor 362 connects electrically to a contact pad 363 on its top surface, which contacts the terminal of the device under test during use. The contact pad 363 may optionally include one or more bumps or textures 364 that may enhance electrical contact and may desirably help scrape off any oxide layers on the terminal that would otherwise inhibit a good electrical connection. The ribbon conductor 362 also connects electrically to one or more contact pad 367 on its bottom surface, which contacts a connection pad on the load board during use.

[00196] Note that the contact pads 363 and 367 are on opposite sides of the conductor 362. They may be connected electrically through the conductor 362, through one or more vias 369. The vias may optionally be located in areas of reduced stress in the conductor 362, which may desirably prolong the life of the conductor 362.

[00197] Note that the ribbon conductor 362 may have a controlled impedance in any or all of the arms or strands 368, and/or in the base 371. In some cases, this controlled impedance may match that of adjacent electrical components, which may reduce reflected losses and may therefore improve the electrical performance of the conductor 362.

[00198] The conductor 362 is drawn in Figure 38 as having four arms 368, each being 90 degrees apart, azimuthally. Alternatively, there may be two, three, five, six, seven, eight, or more than eight arms 368.

[00199] In some cases, each arm 368 may have a conducting portion, denoted by base 371 and its surrounding area, and an insulating area, denoted by non-contiguous areas 366. In some cases, a pair of opposite arms may have a transverse offset with respect to each other, so that if the opposite arms do contact each other during use, when the spring 362 is compressed, then the electrically conductive areas 371 of opposite arms do not touch each other. For arms with this transverse offset, a conductive area of one arm may contact an insulating area of the opposite arm without significant negative effects.

[00200] In some cases, the conductor, or membrane, 362 is made as one piece.

In other cases, the conductor is fabricated as multiple strips that are adhered to opposite side of the spring 361 on the bottom to allow for maximum flexing of the membrane substrate.

[00201] In some cases, the membrane could be completely plated for higher current applications or could be a designed control impedance line that matches the device under test. In some cases, the top portion of the membrane could include grooves, which may enhance electrical contact with the terminal of the device under test. Such enhancement may include a wipe function to remove oxides. The grooves may be cut into the membrane, or plated as beam in the membrane to provide a sharp bevel to remove the oxides.

[00202] Note that this ribbon conductor 362 keeps the same electrical path length, regardless of the compression level of the spring 362. This is advantageous, compared to running current through the spring itself, because the electrical properties of the conductor 362 do not vary with the compression level of the spring 362.

[00203] In some cases, a plating on the side of membrane could also be used to add more current capability or provide shielding. If two or multiple strips are used and not tied to each other or to conducting spring two separate paths are generated from device to load board for Kelvin (Force or sense) applications and would contact separate load board pads.

CLAIMS

We claim:

1. A test fixture (120) for forming a plurality of temporary mechanical and electrical connections between a device under test (130) and a load board (160), comprising:
 - a membrane (150) for mechanically and electrically contacting the load board (160);
 - a plurality of vias (151) disposed in the membrane (150), each via (151) in the plurality being associated with a terminal (131) on the device under test (130) and a contact pad (161) on the load board (160), each via (151) in the plurality having an electrically conducting wall for conducting current between the terminal (131) and the contact pad (161); and
 - a plurality of springs (152) disposed within the plurality of vias (151) in a one-to-one correspondence, each spring (152) in the plurality providing a mechanical resisting force to the terminal (131) when the device under test (130) is engaged with the test fixture (120).
2. The test fixture (120) of claim 1, further comprising:
 - a contact membrane (140);
 - a top contact pad (141) disposed on a first side of the contact membrane (140) for directly contacting electrically the terminal (131); and
 - a bottom contact pad (142) disposed on a second side of the contact membrane (140) opposite the first side, for directly contacting the electrically conducting wall of the via (151);wherein the top contact pad (141) and the bottom contact pad (142) are permanently electrically connected.
3. The test fixture (120) of claim 2, wherein the top contact pad (141) comprises a plurality of arms, each arm in the plurality having a fixed end and a free end, the free end extending generally radially inward from a periphery adjacent to the wall of the via (151), the free end being generally longitudinally deflectable by the terminal (131).

4. The test fixture (120) of claim 1, wherein at least one spring (251) in the plurality includes an enlarged turn (253) of the spring (251) that anchors the spring (251) to a ridge (252) in the wall of the via (151).
5. The test fixture (120) of claim 1 further including:
a pair of open-ended tubes (202, 203, 392, 393), the open end of one tube (203, 393) fitting within the open end of the other tube (202, 392), the tubes being longitudinally slidable with respect to each other, the tubes (202, 203, 392, 393) surrounding and housing the spring element (201, 391).
6. The test fixture (120) of claim 5,
wherein the pair of tubes (202, 203) are electrically insulating; and
wherein each via (151) in the plurality has an electrically conducting wall for conducting current between the terminal (131) and the contact pad (161).
7. The test fixture of claim 1 further including a plurality of electrically conducting ribbons (222) in a one-to-one correspondence with the plurality of vias (151), each ribbon (222) configured for conducting current between the corresponding terminal (131) and the corresponding contact pad (161), each ribbon (222) including at least one strand interwoven with the corresponding spring (221) and electrically connecting a first longitudinal end of the corresponding spring (221) to a second longitudinal end opposite the first longitudinal end.
8. The test fixture (120) of claim 7, wherein each strand of each electrically conducting ribbon (222) in the plurality extends to a cantilevered arm (223) at the longitudinal end facing the device under test (130).

9. The test fixture of claim 1 further including a ribbon conductor (362) for conducting current between the terminal on the device under test and the contact pad of the load board, the ribbon conductor (362) comprising a plurality of conductive strands (368); wherein each strand (368) in the plurality:
- extends along a longitudinal extent of the spring (361);
 - is electrically connected to the other strands (368) in the plurality;
 - terminates in a contact pad (363) for mechanically and electrically contacting the terminal on the device under test; and
 - has an electrical path length that is invariant with respect to the compression of the spring (361).
10. The test fixture of claim 9, wherein each strand (368) in the plurality is equally spaced azimuthally from adjacent strands (368) in the plurality.
11. The test fixture of claim 9, wherein each strand (368) in the plurality is laterally offset from opposite strands (368) in the plurality.
12. The test fixture of claim 9, wherein each strand (368) in the plurality comprises an electrically conducting portion (371) laterally surrounded by an electrically insulating portion (366).