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(54) **ADAPTER APPARATUS WITH SLEEVE SPRING CONTACTS**

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H01R 13/33 (2006.01)

(52) **U.S. Cl.** **439/841**; 439/66

(58) **Field of Classification Search** 439/841, 439/66, 840

See application file for complete search history.

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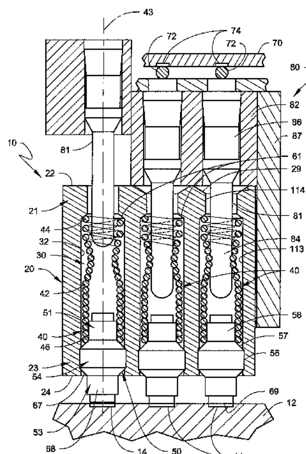
(57) **ABSTRACT**

An adapter apparatus includes a substrate having a plurality of openings defined therethrough. Further, a sleeve spring contact is mounted in each of the openings.

12 Claims, 7 Drawing Sheets



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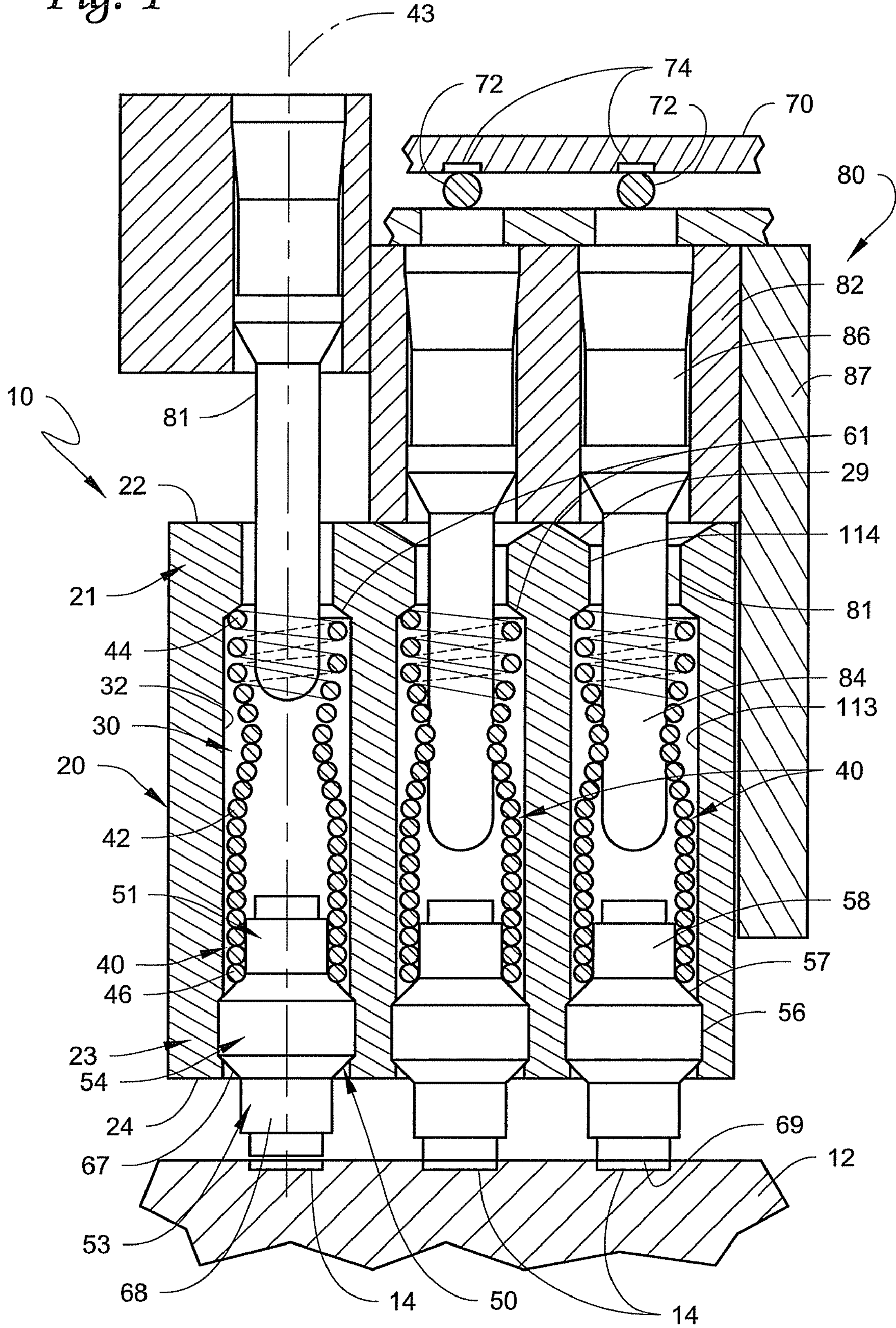
Fig. 1
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Fig. 2A

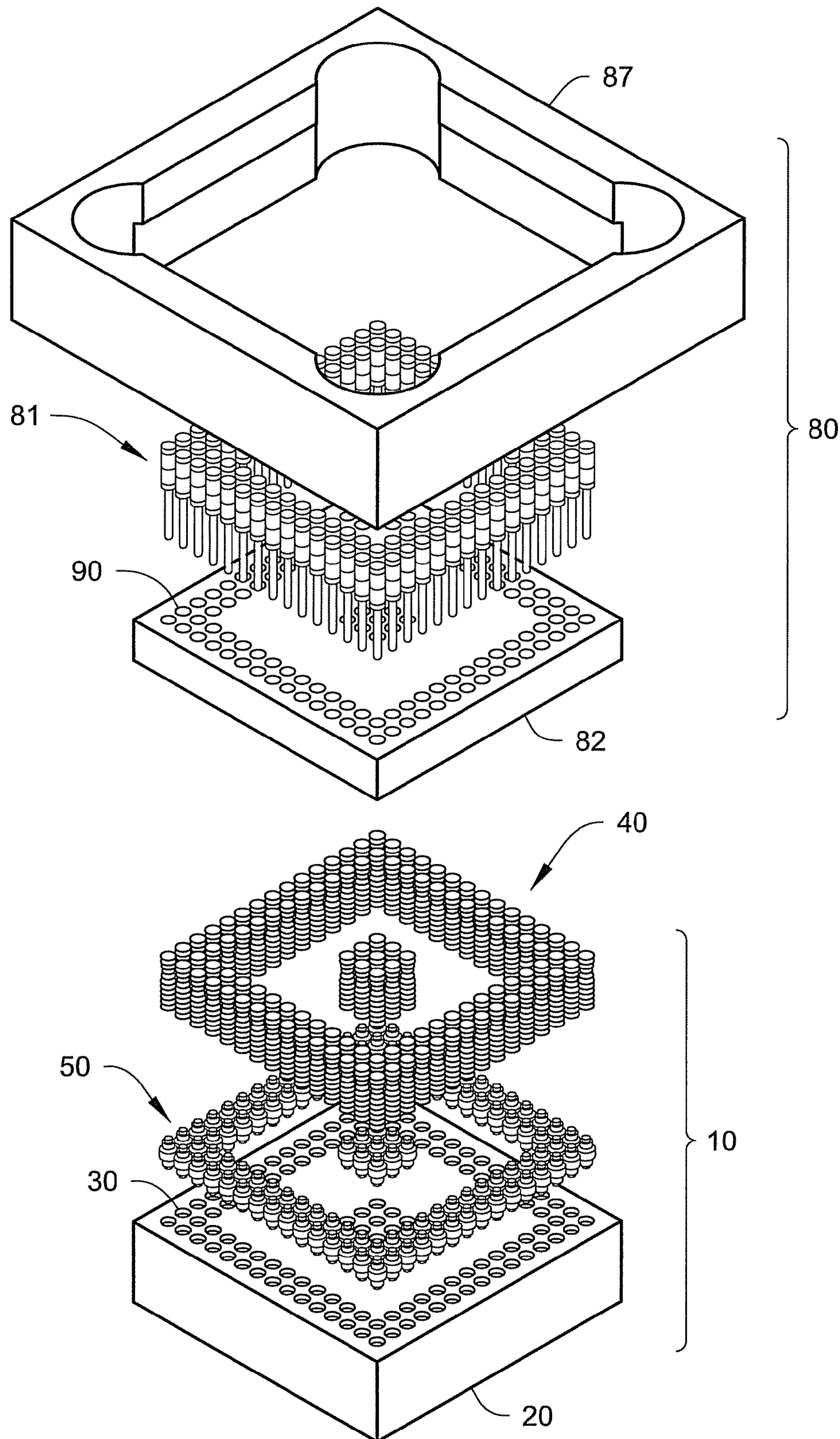


Fig. 2B

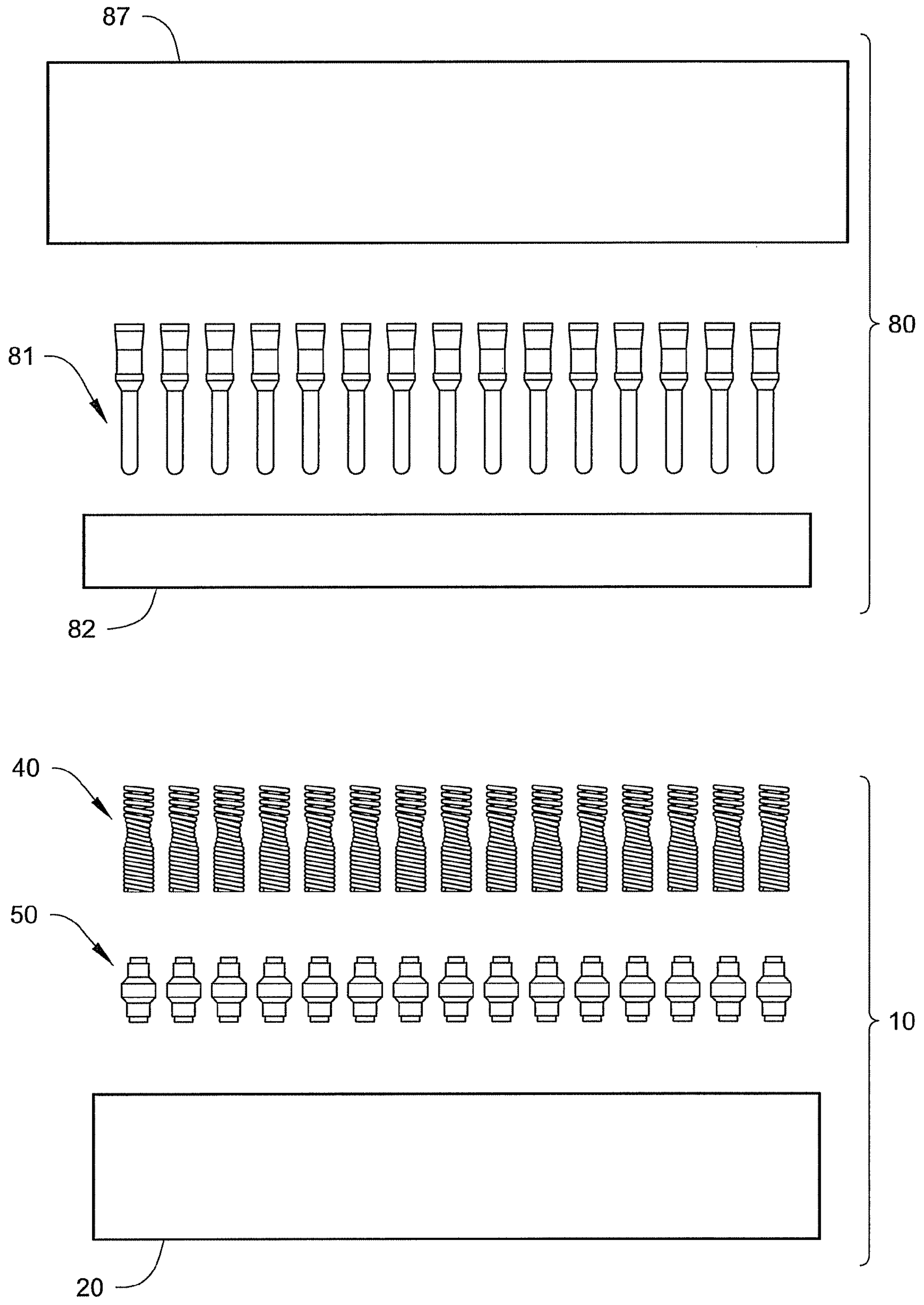


Fig. 3A

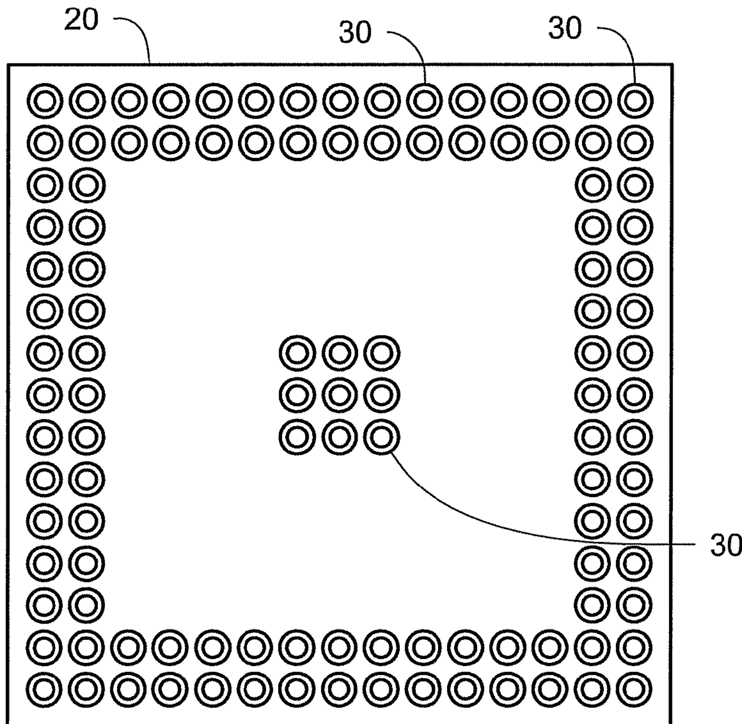


Fig. 3B

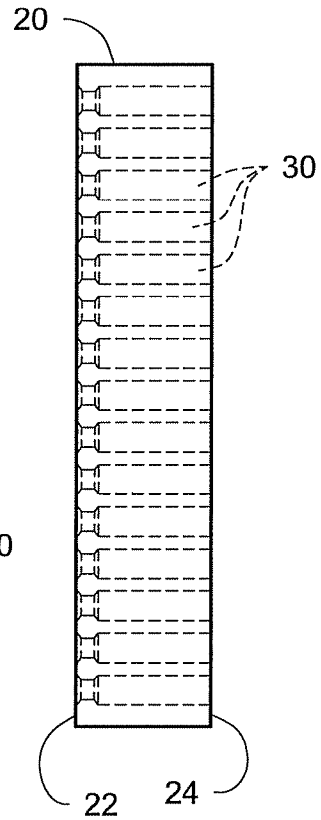


Fig. 3C

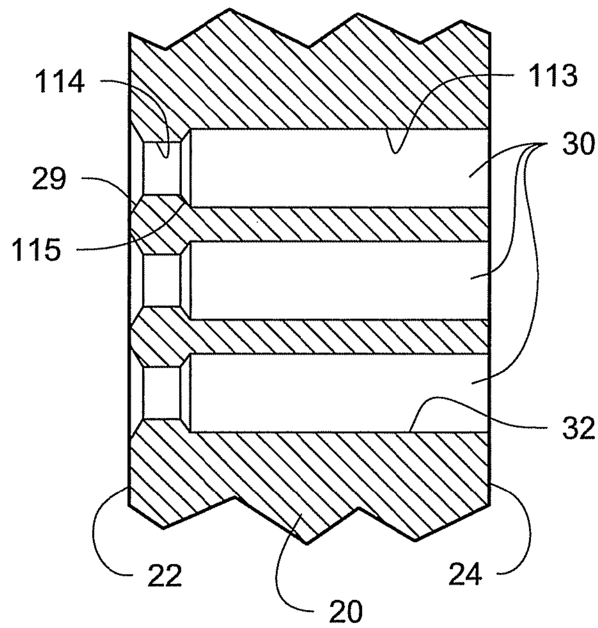


Fig. 4A

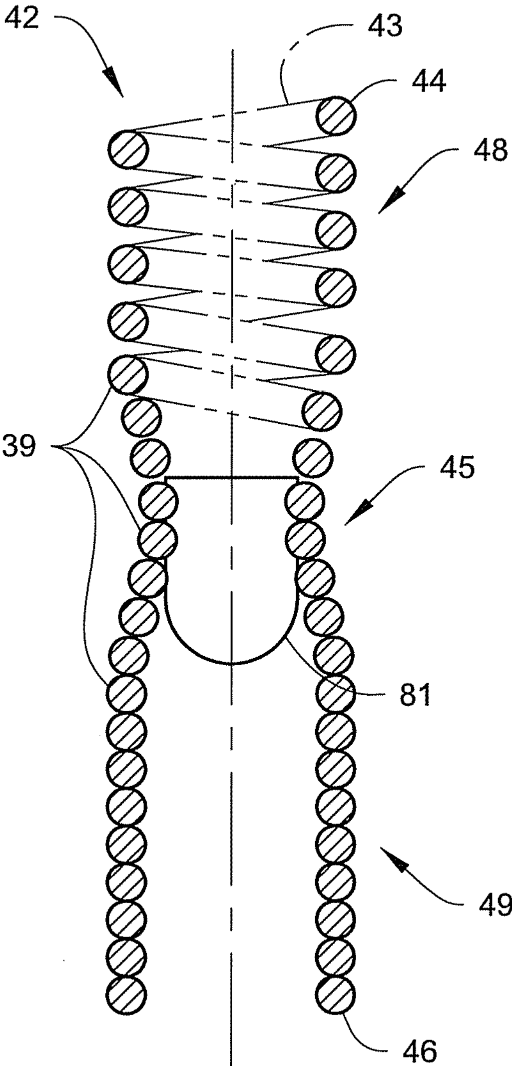


Fig. 4B

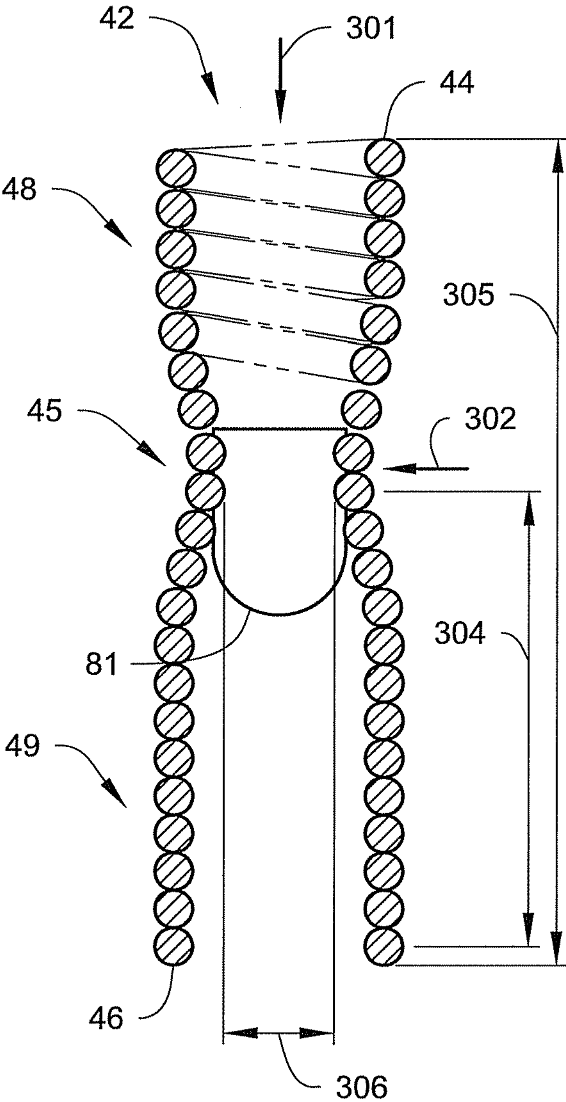


Fig. 5B

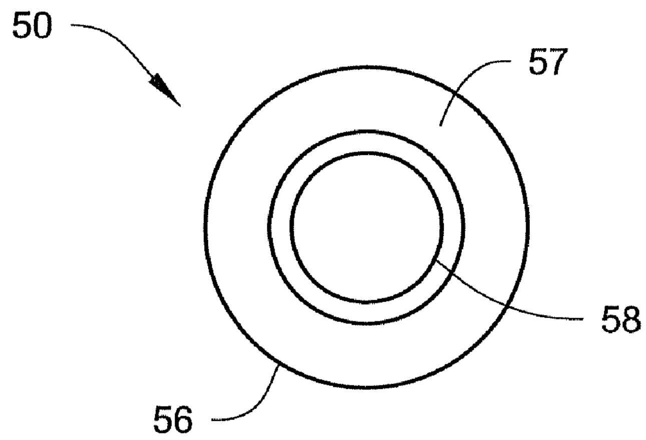


Fig. 5A

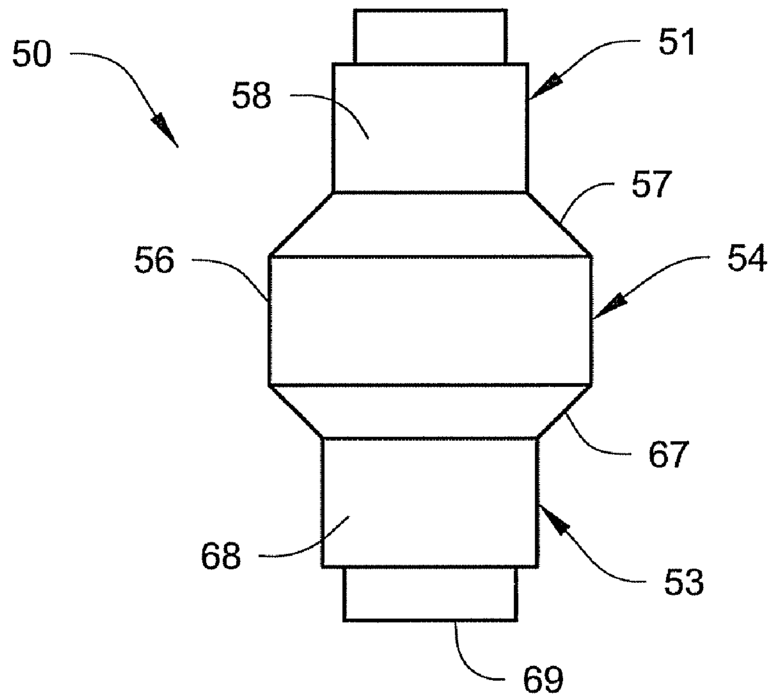
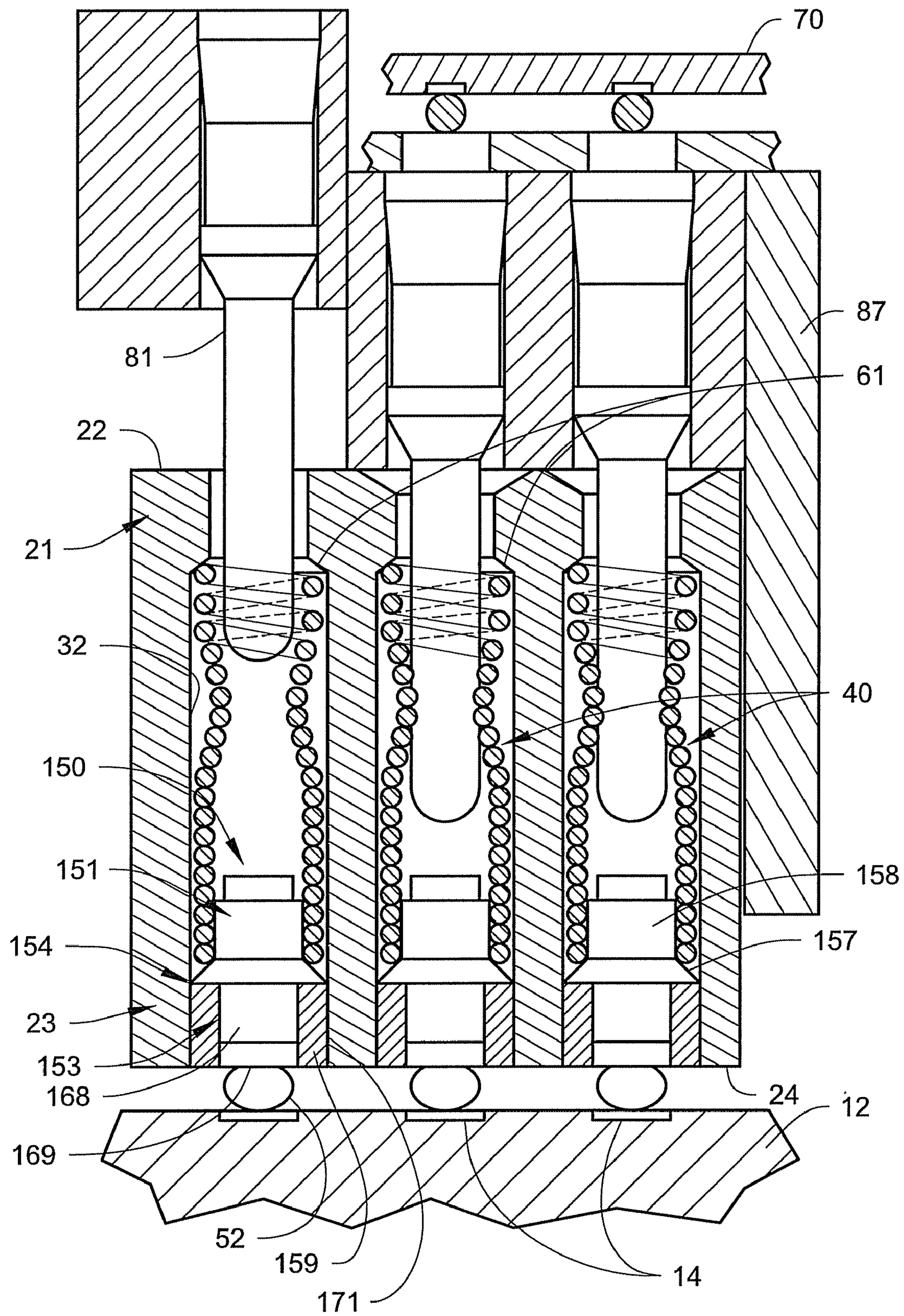


Fig. 6



ADAPTER APPARATUS WITH SLEEVE SPRING CONTACTS

BACKGROUND

The present invention relates generally to adapters for use with packaged devices or other adapter apparatus (e.g., male pin adapters).

Certain types of integrated circuit packages are becoming increasingly popular due to their occupancy area efficiency. In other words, they occupy less area on a target board on which they are mounted while providing a high density of contact terminals. For example, such high density package types may include a ball grid array or land grid array package.

Generally, for example, ball grid array packages contain an integrated circuit having its die bond pads electrically connected to respective conductive solder spheres that are distributed on the bottom surface of the package in an array. A target printed circuit board typically has formed on its surface a corresponding array of conductive pads which align with the array of solder spheres for electrically mounting the ball grid array package on the target board.

The target board typically includes other conductive traces and elements which lead from the array of conductive pads used for mounting the ball grid array package to other circuitry on the board for connecting various components mounted thereon. Typically, to mount such a ball grid array package to a target board, the package is positioned with the array of solder spheres corresponding to the array of conductive pads on the target board. The resulting structure is then heated until the solder spheres are melted and fused to the conductive pads of the target board.

Such area efficient packaging (e.g., ball grid array packages) provide a high density of terminals at a very low cost. Also, this packaging provides for limited lead lengths. Limited lead lengths may reduce the risk of damage to such leads of the package, may provide for higher speed product, etc.

Generally, circuit boards and/or components mounted thereon are tested by designers as the circuit boards are being developed. For example, for a designer to test a circuit board and/or a ball grid array package mounted thereon, the designer must first electrically connect the solder spheres on the ball grid array package to the target circuit board. As described above, this generally includes mounting the ball grid array package on the target board and heating the solder spheres to fuse the solder spheres to the conductive pads of the target board.

Therefore, the package may be prevented from being used again. It is desirable for various reasons to use package adapters for mounting the packages and reuse ball grid array packages after testing. For example, such ball grid array packages may be relatively expensive. Further, for example, once attached, the solder spheres are not accessible for testing. In addition, it is often difficult to rework the circuit board with packages soldered thereon.

Various adapters which are used for electrically connecting high density packaged devices to a target printed circuit board are known. Various intercoupling components are used to provide such adapters. For example, U.S. Pat. No. 6,007,348 to Murphy, issued 28 Dec. 1999, entitled “Solder Sphere Terminal,” and U.S. Pat. No. 6,325,280 to Murphy, issued 4 Dec. 2001, entitled “Solder Sphere Terminal” describe several adapter apparatus for use in mounting ball grid array packages, as well as intercoupling components of other conventional adapter devices, in many instances such adapters have terminals (e.g., female socket pins) configured for receiving a mating terminal (e.g., female socket pins configured to receive male pins). For example, such female socket pins may be press-fit into openings formed in an insulative material so as to provide a contact for receiving a male pin.

Conventional female pin contacts are generally constructed with use of a stamped clip which is formed in a circle with separate fingers which are pushed aside when a male pin is inserted. For example, such a clip is generally manufactured using a stamping or rolling process (e.g., with a material such as berylium copper alloy).

However, such clip manufacturing can be prohibitively costly due to the necessary tooling required when the sockets in which the female socket pins are used have a very small pitch (e.g., in the 0.5 millimeter range). Further, the tooling to form such female clips can be difficult to miniaturize because of the inherent inaccuracies of stamping very small parts.

SUMMARY

The disclosure herein relates generally to adapter apparatus that use sleeve springs to provide a female socket pin into which a male pin may be inserted. For example, such a sleeve spring may overcome the manufacturing problems of stamped clip type female contacts.

One exemplary adapter apparatus disclosed herein includes a substrate (e.g., a substrate with a plurality of openings defined therethrough) and a plurality of conductive sleeve spring contacts. Each of the plurality of sleeve spring contacts is mounted within a corresponding opening of the plurality of openings (e.g., in a compressed state). Each of the plurality of sleeve spring contacts includes a plurality of windings about an axis of the sleeve spring contact forming at least a first winding section and a second winding section (e.g., the second winding section of the sleeve spring contact may include one or more windings in contact with adjacent windings, and further one or more windings of the second winding section may include windings having a smaller diameter than other windings of the second winding section for making contact with a male pin when the male pin is inserted along the axis of the sleeve spring contact).

In one or more embodiments of the adapter apparatus, the first winding section of the sleeve spring contact may include one or more windings that are not in contact with adjacent windings to allow compression of the sleeve spring contact when being mounted in a corresponding opening of the plurality of openings.

In one or more embodiments, the sleeve spring contact may further include a conductive pin element to mount the plurality of windings within the opening in a compressed state. For example, the conductive pin element may include a first end portion having an engagement surface for contact with an end of the plurality of windings and a second end portion opposite the first end portion configured for attachment to corresponding pads of a target board.

Further, in one or more embodiments, the substrate may includes a first surface region and a second surface region opposite the first surface region. Each of the openings may be defined through the substrate from the first surface region to the second surface region. An engagement surface may define at least a portion of the opening proximate the first surface region to engage a first end of the plurality of windings mounted within the opening, and further, each of the conductive sleeve spring contacts may include a conductive pin element mounted at least partially within the opening proximate the second surface region (e.g., by press-fit or using a curable material). For example, the conductive pin element may include an engagement surface to engage a second end of the plurality of windings mounted within the opening.

Another embodiment of an adapter apparatus may include a plurality of conductive sleeve spring contacts. For example, each sleeve spring contact may include a conductive sleeve spring extending between a first spring end and a second spring end along a spring axis. Each sleeve spring may include a first winding section that includes a plurality of windings about the spring axis terminating in the first spring end and a second winding section that includes a plurality of windings terminating in the second spring end. For example, the plurality of windings of the second winding section of the sleeve spring may include windings in contact with adjacent windings and at least one or more windings that have a smaller diameter than other windings of the second winding section for making contact with a male pin when the male pin is inserted along the axis of the sleeve spring. Further, the first winding section of the sleeve spring may include a plurality of windings that are not in contact with adjacent windings.

In one or more embodiments of the adapter apparatus, each of the plurality of conductive sleeve spring contacts are mounted in a corresponding opening of a plurality of openings defined in a substrate (e.g., each of the conductive sleeve springs may be mounted within the opening in a compressed state by a conductive pin element)

Yet further, one exemplary embodiment of a method for use in forming an adapter apparatus may include providing a substrate including a plurality of openings defined therethrough. The substrate may include a first surface region and a second surface region opposite the first surface region (e.g., each of the openings may be defined through the substrate from the first surface region to the second surface region). Further, the method may include inserting a conductive sleeve spring into each of the plurality of openings at the second surface region (e.g., each conductive sleeve spring may extend between a first spring end and a second spring end along a spring axis, each sleeve spring may include a first winding section that includes a plurality of windings about the spring axis terminating in the first spring end and a second winding section that includes a plurality of windings terminating in the second spring end, the plurality of windings of the second winding section of the sleeve spring may include windings in contact with adjacent windings and at least one or more windings that have a smaller diameter than other windings of the second winding section for making contact with a male pin when the male pin is inserted along the axis of the sleeve spring, and further, the first winding section of the sleeve spring may include a plurality of windings that are not in contact with adjacent windings). Each of the conductive sleeve springs is mounted such that the sleeve spring is at least partially compressed within the opening (e.g., using a conductive pin element inserted at least partially in opening).

The above summary of the present invention is not intended to describe each embodiment or every implementation of the present invention. Advantages, together with a more complete understanding of the invention, will become apparent and appreciated by referring to the following detailed description and claims taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a generalized illustrative diagram of one exemplary embodiment of a portion of an adapter apparatus including a sleeve spring contact for use in mounting a packaged device relative to a target board.

FIG. **2**A is an exploded perspective view of one exemplary embodiment of an adapter apparatus such as illustratively shown in FIG. **1**.

FIG. **2**B is a side view of the exemplary embodiment of the adapter apparatus of FIG. **2**A.

FIGS. **3**A-**3**C show a plan view, a side view, and a more detailed cross-section view of a portion, respectively, of an exemplary embodiment of a substrate usable to provide an adapter apparatus such as the adapter apparatus of FIG. **2**A.

FIGS. **4**A-**4**B show an illustrative side view of a sleeve spring in its uncompressed free state and an illustrative side view of a sleeve spring in its compressed state when held within a substrate for use in providing a female socket portion of an adapter apparatus such as the adapter apparatus of FIG. **2**A.

FIGS. **5**A-**5**B show a side view and a plan view, respectively, of one exemplary embodiment of a pin element usable to provide an adapter apparatus such as the adapter apparatus of FIG. **2**A.

FIG. **6** is a generalized illustrative diagram of another exemplary embodiment of a portion of an adapter apparatus including a sleeve spring contact for use in mounting a packaged device relative to a target board.

The figures are rendered primarily for clarity and, as a result, are not necessarily drawn to scale.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

In the following detailed description of illustrative embodiments, reference is made to the accompanying figures of the drawing which form a part hereof, and in which are shown, by way of illustration, specific embodiments which may be practiced. It is to be understood that other embodiments may be utilized and structural changes may be made without departing from (e.g., still falling within) the scope of the disclosure presented hereby.

Exemplary adapter apparatus shall generally be described with reference to FIGS. **1**-**6**. It will be apparent to one skilled in the art that elements from one embodiment may be used in combination with elements of the other embodiments, and that the possible adapter apparatus embodiments using features set forth herein is not limited to the specific embodiments described. Further, it will be recognized that the embodiments described herein will include many elements that are not necessarily shown to scale. Further, it will be recognized that the size and shape of various elements herein may be modified without departing from the scope of the present disclosure, although one or more shapes and sizes may be advantageous over others.

FIG. **1** shows a generalized diagrammatic view of an exemplary adapter apparatus **10**. The adapter apparatus **10** includes a substrate **20**. Substrate **20** comprises a body of material extending between a first surface **22** and a second surface **24**. In one embodiment of substrate **20**, the first surface **22** and the second surface **24** are planer surfaces that generally lie parallel to one another.

The substrate **20** may be formed of any suitable insulative material (e.g., polyimide materials). Preferably, substrate **20** is formed of a high temperature material (e.g., a material that is suitable for use in temperatures that exceed 125° C.). For example, the substrate **20** may be formed of one or more materials such as polyetheretherketone (PEEK), Ceramic filled PEEK or other grades of PEEK, Torlon, FR4, G10, Kapton, or Rogers R04350.

In one embodiment, the substrate **20** may be of a size generally equivalent to a packaged device (e.g., packaged device **70**) which is to be mounted using the adapter apparatus **10**. However, one skilled in the art will recognize that the size and shape of the substrate material **20** may vary based on the

application of the adapter apparatus (e.g., the adapter apparatus may be configured to mount more than one packaged device).

The present invention may be used to mount various types of packaged devices, including, but not limited to, for example, surface mount devices, such as ball grid array packages, land grid array packages, quad flat no leads (QFN) devices, column grid array packages, non-solder ball packages, other packaged devices with surface mount pads, etc. One will recognize that the configuration of the adapter apparatus may be different depending on the type of the packaged device being mounted (e.g., the apparatus being different or the same for a package including solder balls versus a non-solder ball package).

As shown in FIG. **1** and FIGS. **3**A-**3**C, in one or more embodiment, the substrate **20** includes a plurality of openings **30** defined through the substrate **20** by one or more surfaces **32**. The openings **30**, as shown in FIG. **1**, are defined through substrate **20** from first surface **22** in first surface region **21** to second surface **24** of substrate **20** in second surface region **23**; second surface region **23** being opposite first surface region **21**. The size and shape of the openings **30** will be dependent upon the structure used to mount conductive sleeve spring contacts in corresponding openings **30**.

In one or more embodiments, as shown in the plan view, the side view, and the partial detailed cross-section view of FIGS. **3**A-**3**C, the substrate **20** may include a plurality of openings **30** proximate the perimeter of the substrate **20** and one or more openings **30** towards the middle of the substrate **20**. However, any number or configurations of openings **30** may be used. Further, each opening **30** may be defined using different diameter surfaces defining different portions of the opening **30**. For example, as further described herein, for mounting the sleeve spring **40** in the opening **30**, the opening **30** may be defined by surfaces **113** and **114** (e.g., each having a different diameter) with a transition surface (e.g., surface **115**) therebetween. For example, the transition surface may be used as an engagement surface for mounting sleeve spring **40** within opening **30** (e.g., the surface may be at an angle of 60 degrees relative to axis **43** or any other angle suitable to engage the spring in a manner such that it can be compressed as described herein). Various configurations of such openings with different defining surfaces may be used to accommodate mounting of the sleeve spring **40**. Such surfaces **32** may be defined by drilling one more holes through the substrate **20**.

Conductive sleeve spring contacts **40** are mounted in each opening **30** defined through the substrate **20**. The sleeve spring contacts **40** may be mounted in the openings **30** in any suitable manner (e.g., using any suitable structure, such as particular configurations of the walls defining the openings **30** or any type of conductive pin element structures) so as to allow a male pin (e.g., such as elongated male pin **81**) to be inserted into the center of a sleeve spring used to provide the sleeve spring contact **40** as described herein. Further, suitable structure for mounting such conductive sleeve spring contacts **40** within the openings may provide a conductive portion for use in electrical connection of the male pin **81**, through the sleeve spring contact **40**, to another conductive element, such as a matching pad **14** on a target board **12** (e.g., a printed circuit board).

In at least one embodiment, each conductive sleeve spring contact **40** generally includes a sleeve spring **42** extending along a spring axis **43** from a first spring end **44** to a second spring end **46**. Such a sleeve spring **42** is shown in an uncompressed state (e.g., a free length state) in FIG. **4**A and a compressed state in FIG. **4**B having a downward force (i.e., a force applied along spring axis **43**) applied thereto. For example, in one embodiment, the downward force **301** is 1.5 times the force **302** at the waist **45** of the sleeve spring **42** (e.g., the waist being the portion of windings that contact the male pin when inserted into the center of the spring along the axis **43**).

In one or more embodiments, each sleeve spring **42** includes a plurality of windings **39** about spring axis **43** forming at least a first winding section **48** and a second winding section **49**. The second winding section **49** of the sleeve spring contact **42** includes one or more windings in contact with adjacent windings (e.g., terminating in the second spring end **46**), and further one or more windings of the second winding section **49** include windings having a smaller diameter than other windings of the second winding section **49** (e.g., providing the waist **45** of the sleeve spring **42**) for making contact with a male pin when the male pin is inserted along the axis of the sleeve spring contact **42** (e.g., the axis being the same as the axis **43** of the sleeve spring **40**).

In one or more embodiments, the first winding section **48** of the sleeve spring **42** includes one or more windings that are not in contact with adjacent windings (e.g., a standard type of spring arrangement) to allow compression of the sleeve spring **42** when mounted in a corresponding opening **30**. In other words, the windings are loosely wound such that the windings may move closer together along the axis **43** when a force is applied (e.g., one or more windings of the section **48** may move into contact with adjacent windings, or may continue to be apart from adjacent windings). At least in one embodiment, the waist **45** of the sleeve spring **40** is directly adjacent the loose windings (e.g., the smaller diameter windings are between the first winding section **48** and the windings of the second winding section **49** that have a larger diameter than those at the waist or mid-section **45**).

At least in one or more embodiments, the plurality of windings **46** are mounted within the opening **30** in at least a partially compressed state at a compressed length **305**. At least in one embodiment, since the windings of the second winding section **49** are in contact with adjacent windings, the length **304** of the second winding section does not substantially change between the uncompressed state (i.e., free length state) and compressed state of the sleeve spring **42**. For example, the sleeve spring **42** may be compressed to a length that is 95 percent or less than the spring's free length, may be compressed to a length that is 90 percent or less than the spring's free length, may be compressed to a length that is 80 percent or less than the spring's free length, or may be compressed to a length that is 70 percent or less than the spring's free length.

In other words, at least in one embodiment, each sleeve spring **42** extends between the first spring end **44** and the second spring end **46** along spring axis **43**. Each sleeve spring **42** includes the first winding section **48** that includes a plurality of windings about the spring axis **43** terminating in the first spring end **44** and the second winding section **49** that includes a plurality of windings terminating in the second spring end **46**. The plurality of windings of the second winding section **49** of the sleeve spring **42** include windings in contact with adjacent windings; wherein at least one or more windings of the second winding section **49** have a smaller diameter than other windings of the second winding section **49** for making contact with a male pin when the male pin is inserted along the axis **43** of the sleeve spring **42**. Further, for example, the first winding section **48** of the sleeve spring **42** may include a plurality of windings that are not in contact with adjacent windings. At least in one embodiment, all of the windings of the second winding section **49** (e.g., the second winding section starting at least where contact is made

between the male pin and the windings, and terminating at the second end of the spring) are in contact with adjacent windings. For example, in one embodiment, the second winding section **49** may be said to start at the winding having the smallest diameter. In one or more other embodiments, the second winding section **49** may be said to start at a winding above the smallest diameter winding towards the first end of the spring).

The sleeve springs **42**, in one or more embodiments, are configured for mounting in openings of a substrate where the pitch of the contacts of the adapter apparatus is in the range of about 0.3 mm to about 0.75 mm. The waist **45** is configured with an inner diameter **306** so as to provide effective contact with a male pin **81** when the male pin **81** is inserted through the center of the sleeve spring **42** and within the windings having a smaller diameter than the other windings of the second winding section **49**.

As shown in FIG. **1**, in one or more embodiments, each of the conductive sleeve springs **42** is mounted within the opening **30** in a compressed state using a conductive pin element **50**. For example, the conductive pin element **50** as shown in FIG. **1**, and in further detail in the side and plan view of FIGS. **5**A-**5**B, includes a first end portion **51** for contact with the second spring end **46** terminating the second winding section **49** and a second end portion **53** opposite the first end portion **51**, e.g., the second end portion as shown in FIG. **1** is configured for attachment to a corresponding pad **14** of a target board **12**.

Further, in one or more embodiments, the conductive pin element **50** is configured to be mounted in a portion of the opening **30** defined at the second surface region **23** of the substrate **20**. For example, as shown in FIG. **1**, the conductive pin element **50** includes a mid-section **54** provided between the first end portion **51** and second end portion **53**. The mid-section **54** has a diameter greater than the diameter of the opening **30** (i.e., orthogonal to the axis **43**) effective to provide an interference fit between the outer surface **56** of the mid-section **54** and surface **32** defining the opening **30** when the conductive pin element **50** is press-fit within the opening **30**. The interference fit is sufficient to maintain the sleeve spring **42** in its at least partially compressed state when loaded into the opening **30**. One will recognize that one or more structures or processes may be used to maintain the sleeve spring **42** in its compressed state within opening **30** (e.g., press-fit of pin element into opening **30**, mounting of a pin element with a curable material as described herein with reference to FIG. **6**, an additional substrate holding the conductive pin element **50**, etc.).

Still further, in one or more embodiments, the first end portion **51** of the conductive pin element **50** includes an engagement surface such as shoulder surface **57** to engage (e.g., contact) the second spring end **46** of the sleeve spring **42** when mounted within the opening **30**. Further, as shown in the exemplary embodiment of FIG. **1**, the first end portion **51** includes an elongate portion **58** that extends within the center of the sleeve spring **42** to assist in holding the sleeve spring **42** in place (e.g., centered in opening **30**).

The engagement surface, such as shoulder surface **57**, acts in cooperation with a shoulder surface (e.g., an engagement surface) **61** that defines at least a portion of the opening **30** proximate the first surface region **21** to engage the first spring end **44** of the sleeve spring **42** when mounted within the opening **30**. In other words, the surface **32** defining the opening **30** includes a surface having at least two different diameters (e.g., surfaces **113** and **114**) with a transition (e.g., surface **115**) therebetween (e.g., the shoulder) to provide an engagement surface for contact with the first spring end **44** of the sleeve spring **42** while allowing a male pin **81** to be inserted into the opening **30** and along axis **43** of the sleeve spring **43**.

One will recognize that the engagement surfaces to engage the first end **44** and second end **46** of the sleeve spring **42** may be provided in any suitable manner. For example, the engagement surface for engaging the first spring end **44** may be provided by surfaces defining the opening **30**, may be provided by a separate element positioned in a portion of the opening defined at the first surface region **21** of the substrate **20**, may be provided by a channel defined to receive the spring end, or may be provided in any other manner sufficient to allow the sleeve spring **42** to be compressed within the opening **30**. Likewise, for example, the engagement surface for engaging the second spring end **46** may be provided by any suitable surfaces (e.g., surfaces of the pin element **50** or other cooperative structural part, such as an end of a tube or cylindrical element used to mount the spring) that allows the sleeve spring **42** to be compressed within the opening **30** (e.g., the sleeve spring **42** being compressed within the opening **30** between an engagement surface such as shoulder surface **61** proximate the first surface region **21** and an engagement surface such as the shoulder surface **57** of the pin element **50**).

Such conductive pin elements and sleeve springs may be formed of any suitable conductive material for providing desired electrical conduction. For example, such conductive elements (e.g., plated or solid) may be formed of brass alloy, gold, nickel, or beryllium/copper alloy. Further, for example, such pin elements may be brass with a gold over nickel plating. Yet further, for example, the sleeve springs may be formed of stainless steel with a gold over nickel plating.

Still further, in one or more embodiments, the second end portion **53** of the conductive pin element **50** includes another shoulder region **67** transitioning from the mid-section **54** to an elongate portion **68**. The elongate portion **68** terminates at a contact surface **69** that may be attached to a matching contact **14** on target board **12**. At least in one embodiment, the contact surface **69** of pin element **50** may be configured for receipt of solder material (e.g., a solder ball, solder sphere, bump, or column) thereon. Depending on the type of material used to form the conductive pin element and the application of the adapter apparatus, at least in one embodiment, solder material may not be needed on the contact surface **69** (e.g., a gold end that can be otherwise soldered to the target board without the need to prevent the end from oxidation).

The conductive sleeve spring contacts **40** shown in FIG. **1** may be referred to as female socket pins mounted in corresponding openings **30** defined through substrate **20** for receiving male pins **81**. In other words, as the adapter apparatus **10** includes female socket type contacts **40**, a male pin adapter **80** may be used in conjunction therewith to mount a device (e.g., a BGA device **70**), to the target board **12**. For example, in one embodiment, the male pin adapter **80** includes a substrate **82** with a plurality of male terminal pins **81** mounted therethrough. Each of the male terminal pins **81** includes a pin portion **84** configured to be received in the sleeve spring contact **40** of adapter apparatus **10** and a contact portion **86** for providing electrical contact with a solder ball **72** of the device **70** (e.g., either directly or indirectly through another board **86** shown generally in FIG. **1**, which may be an interposer, another adapter apparatus, etc.).

Further, for example, as shown in FIG. **1** and not to be considered limiting to the disclosure presented herein, the adapter apparatus **10** may be employed to mount a packaged device **70** (e.g., a BGA package) to target board **12**. Target board **12** includes a pattern of contact elements **14** corresponding to a plurality of solder balls **72** of the ball grid array

device **70**. The solder balls **72** are provided on a pattern of contact pads **74** of the ball grid array device **70**.

Solder material, as used herein, may be any suitable type of solder material generally known in the art. Such suitability will generally depend on the application for which the adapter apparatus is being used. For example, the solder material may include solder balls as shown in FIG. **1**, solder films, solder spheres, partial solder spheres, solder columns, or any other suitable size and shape of material. Further, for example, the solder material may include eutectic 63/37 SnPb solder balls or solder spheres, or may be formed of lead free solder alloys such as SAC305 (Sn,Ag3.0,Cu0.5).

In other words, use of a sleeve spring **40** as shown herein provides a female socket pin that overcomes one or more of the problems with conventional stamped contacts. Generally, the sleeve spring **40** includes the two main sections; the bottom contains the second winding section **49** where solidly wound windings of the spring have a midsection of smaller and then larger diameter windings forming a "waist" **45** at the center of the solid windings. Each winding in this area solidly contacts the adjacent winding. This is beneficial for supplying a very low inductance electrical path, and therefore, very high frequency response. The loose windings at the top of the sleeve spring **42** in the first winding section **48** provide a downward force when compressed (e.g., keeping all the windings of the second winding section in contact with one another).

Further, as described herein, FIGS. **4**A and **4**B show the sleeve spring **42** in use as part of the sleeve spring contact **40**. FIG. **4**A shows a loose spring **40** before it is compressed in a cavity and FIG. **4**B shows the spring **40** compressed in a cavity. A male pin **81** is inserted into the center of the spring **40** and causes the waist **45** of the sleeve spring **40** to expand and provide contact from the male pin **81** to anything contacting the sleeve spring **40** (e.g., the pin conductor or other structure).

As described herein, in one or more embodiments, the sleeve spring **40** is held in the opening **30** defined in the substrate **20** with the smaller diameter hole formed by surface **114** through the substrate **20** to the top surface **22**. The sleeve spring **40** is held in the opening by the conductive pin element **50** that can be held in place in a portion of the opening **30** by press-fit or a curable solid material. In one or more embodiments, the sleeve spring **40** is inserted into the opening **30** and then the conductive pin element **50** is inserted thereafter into the opening from the same side to hold the spring **40** in the opening **30** in a compressed state. This assembly of substrate **20** with openings **30**, springs **40**, and solidly attached pin elements **50** at the bottom, can then be soldered to a series of matching pads **14** on a target PCB **12**. The pin elements **50** can either be solid metal as shown, or optionally have solder balls attached to the bottom contact surface **69** of pin element **50** to emulate a BGA chip.

The male pin assembly or adapter **80** can then be inserted into the female adapter apparatus **10** that includes the sleeve springs **40** such that a chip or other electronic assembly can be connected to BGA pads or pattern on a target board **12**. The male pins **81** of the male pin adapter **80** expands the sleeve springs **40**. In addition, the loose wound spring area (e.g., the first winding section **48**) provides a vertical force such that the solid spring area cannot become unsolid from forces from temperature transitions or vibration; thus keeping its high frequency characteristics under the various situations it may be expected to operate.

FIGS. **2**A-**2**B show an exploded perspective view and an exploded side view, respectively, of one exemplary embodiment of components of the adapter apparatus **10** and male pin adapter **80**, such as illustratively shown in FIG. **1**. The adapter apparatus **10** includes the substrate **20**, including the first surface **22** and a second surface **24** spaced apart therefrom. The adapter apparatus **20** further includes the conductive sleeve springs **40** to be mounted within openings **30** defined through substrate **20** from first surface **22** to second surface **24** using the conductive pin elements **50**, such as, for example, described with reference to FIG. **1**. The conductive pin element **40** may be press-fit within the openings **30** such as described with reference to FIG. **1**, may be mounted within the openings **30** using a curable material as is described herein with reference to FIG. **6**, or may be mounted in any other suitable manner.

The adapter apparatus **10** may be assembled as described herein with reference to the other Figures. For example, the adapter apparatus **10** is assembled to provide the contact surfaces **69** of conductive pin elements **50** at a first side of the adapter apparatus **10**, for example, for connection to one or more pads **14** of a target board **12**. Further, for example, the adapter apparatus **10** is assembled to provide a receiving region within the sleeve spring contact **40** for mating with a male terminal pin, such as a male terminal pin **81** of the male adapter apparatus **80**.

The male adapter apparatus **80** as shown in FIGS. **2**A-**2**B includes the substrate **82** having a plurality of openings **90** defined therethrough for receiving and holding the plurality of male terminal pins **81** configured for mating with the adapter apparatus **10** (e.g., press-fit in the openings **90**). The male adapter apparatus **80** may be configured in any suitable manner for presenting the pins to mate with the sleeve springs contacts **40** of the adapter apparatus **10**. For example, various components may be used to assist the mating of the male terminal pins **81** with the sleeve spring contacts **40**. For example, as shown in FIGS. **1** and **2**A-**2**B, a shroud **87** about the perimeter of the substrate **82** may be used for alignment of the male pin adapter **80** with adapter apparatus **10** (e.g., and thus, alignment of the male pins **81** with the axes **43** of the sleeve springs **40**). Further, for example, a guiding surface (e.g., a beveled or countersunk guiding surface **29**) at the first surface **22** about the opening **30** may be used to guide the male pins **81** into the openings **30**.

As described herein, various mounting structures and mounting processes may be used to provide the conductive sleeve spring contacts **40** within the openings **30** defined through substrate **20**. For example, a press-fitting of the conductive pin element **50** within the opening **30** to compress the sleeve spring **40** in the opening has been described herein. Further, a conductive pin element may also be mounted at least partially within the opening using a curable material to maintain the sleeve spring **40** in a compressed state as shown in FIG. **6**.

FIG. **6** is substantially similar to FIG. **1**, and therefore only components that differ from FIG. **1** will be denoted with different references numerals. For example, as shown in FIG. **6**, a conductive pin element **150** is mounted in the opening **30** at the second surface region **23** using a curable material **152**. One will recognize that the steps of such a mounting process may vary and the present disclosure is not limited to any particular described mounting process. The process for mounting the conductive pin element **150** in the opening **30** may include one or more of the steps or features as described in U.S. patent application Ser. No. 11/069,102 entitled "Adapter Apparatus with Conductive Elements Mounted Using Curable Material and Methods Regarding Same" filed 1 Mar. 2005, and incorporated herein by reference thereto.

For example, after drilling the openings **30** in the substrate, the plurality of sleeve springs **40** and the conductive pin

elements **150** may be inserted into corresponding defined openings **30**. Although any suitable insertion technique may be used, in one exemplary embodiment, vibrational loading of the conductive elements may be employed as known to those skilled in the art.

The conductive pin elements **150**, for example, may each include a mid-section **154** provided between a first end portion **151** and a second end portion **153**. The mid-section **154** may have a diameter substantially equal to or slightly less than the diameter of the opening **30** (i.e., orthogonal to the axis **43**). Still further, in one or more embodiments, the first end portion **151** of the conductive pin element **150** may include an engagement surface such as shoulder surface **157** to engage the second end of the sleeve spring **42** when mounted within the opening **30**. Further, as shown in the exemplary embodiment of FIG. **6**, the first end portion **151** may include an elongate portion **158** that extends within the center of the sleeve spring **42** to assist in centering and hold the sleeve spring **42** in place. The engagement surface, such as shoulder **157**, acts in cooperation with a shoulder surface (e.g., an engagement surface) **61** that defines at least a portion of the opening **30** proximate the first surface region **21** to engage the first end **44** of the sleeve spring **42** when mounted within the opening **30** such as described with reference to FIG. **1**.

Still further, in one or more embodiments, the second end portion **153** of the conductive pin element **150** includes another elongate portion **168**. The elongate portion **168** terminates at a contact surface **169** that may be attached to a matching contact **14** on target board **12**. At least in one embodiment, the contact surface **169** of pin element **150** may be configured for receipt of solder material **52** (e.g., a solder ball, solder sphere, bump, or column) thereon. Further, in one or more embodiments, the contact surface **169** may be flush with the substrate surface **24** or it may extend past the surface **24** (e.g. protrude from the opening **30**). Depending on the type of material used to form the conductive pin element and the application of the adapter apparatus, at least in one embodiment, solder material may not be needed on the contact surface **169**.

At least a portion of the second end portion **153** has a diameter less than the opening **30** so as to provide a curable material receiving region **171** between the pin element **150** and the surface **32** defining the opening **30** when at least a portion of the pin element **150** is positioned within the opening **30**. With the plurality of conductive pin elements **150** inserted into the corresponding defined openings or holes **30**, each of the conductive pin elements **150** may be mounted in a corresponding opening **30** using a curable material **159**.

For example, the curable material **159** may be provided into the curable material receiving regions **171** at the second surface **24** of the substrate **20**. For example, the curable material may be provided with any suitable devices, such as dispensing devices, spinning devices, spreading devices (e.g., squeegee devices), etc. The present disclosure is not limited to any particular device. However, at least in one embodiment, a device for forcing some of the curable material **159** into the curable material receiving regions **171** is used. Thermal treatment may then be used to cure the curable material **159** received in the openings **30**. However, depending on the type of curable material employed, other curing steps may be used and/or required (e.g., ultraviolet light application for a UV curable material). After curing, excess cured material may be removed at the surface **24** of the substrate **20** to expose the contact surfaces **169** of the conductive pin elements **150**.

The curable material **159** may include any suitable curable adhesive material that provides insulative functionality. For

example, such curable material may include UV-curable material or heat curable material (e.g., epoxy materials), or any other curable materials (e.g., acrylic materials). Further, for example, the curable material may be formed of an epoxy, such as DP-270, DP-100, or DP-420 epoxy available from 3M Corporation. Generally, the thermal characteristics of the cured material is preferably like those of the substrate material (e.g., similar thermal expansion coefficients).

At least in one embodiment, curable material **159** proximate (e.g., at the entry of the opening **30**) the surface **24** of substrate **20** is formed so as to completely block entry of any material (e.g., solder) into the openings **30**. For example, the entire curable material receiving region **171** radially about the conductive pin element **150** at the surface **24** of the substrate **20**, and at least a predetermined distance into the opening **30** from surface **24**, is entirely filled with curable material **159**. When in a cured state, such material provides for blocking entry of material into the opening **30**.

All patents, patent documents, and references cited herein are incorporated in their entirety as if each were incorporated separately. This disclosure has been provided with reference to illustrative embodiments and is not meant to be construed in a limiting sense. As described previously, one skilled in the art will recognize that other various illustrative applications may use the techniques as described herein to take advantage of the beneficial characteristics of the apparatus and methods described herein. Various modifications of the illustrative embodiments, as well as additional embodiments of the invention, will be apparent to persons skilled in the art upon reference to this description.

The invention claimed is:

1. An adapter apparatus comprising:

a substrate, wherein a plurality of openings are defined through the substrate, wherein the substrate comprises a first surface region and a second surface region opposite the first surface region, wherein each of the openings is defined through the substrate from the first surface region to the second surface region, wherein an engagement surface defines at least a portion of the opening proximate the first surface region to engage a first end of the plurality of windings mounted within the opening; and

a plurality of conductive sleeve spring contacts, wherein each of the plurality of sleeve spring contacts is mounted within a corresponding opening of the plurality of openings, wherein each of the plurality of sleeve spring contacts comprises a plurality of windings about an axis of the sleeve spring contact forming at least a first winding section and a second winding section, wherein the second winding section of the sleeve spring contact comprises at least three or more windings in contact with adjacent windings, wherein one or more windings of the second winding section comprise windings having a smaller diameter than other windings of the second winding section for making contact with a male pin when the male pin is inserted along the axis of the sleeve spring contact, and further wherein each of the conductive sleeve spring contacts comprises a conductive pin element mounted at least partially within the opening proximate the second surface region, wherein the conductive pin element comprises an engagement surface to engage a second end of the plurality of windings mounted within the opening, and further wherein the conductive pin element is mounted at least partially within the opening proximate the second surface region using a curable material such that the plurality of windings are at least partially compressed within the opening

between the engagement surface proximate the first surface region and the engagement surface of the conductive pin element.

2. The adapter apparatus of claim **1**, wherein the first winding section of the sleeve spring contact comprises one or more windings that are not in contact with adjacent windings to allow compression of the sleeve spring contact when being mounted in a corresponding opening of the plurality of openings.

3. The adapter apparatus of claim **1**, wherein the plurality of windings are mounted within the opening in a compressed state.

4. The adapter apparatus of claim **3**, wherein the sleeve spring contact further comprises a conductive pin element to mount the plurality of windings within the opening in a compressed state, wherein the conductive pin element comprises a first end portion comprising an engagement surface for contact with an end of the plurality of windings and a second end portion opposite the first end portion configured for attachment to corresponding pads of a target board.

5. The adapter apparatus of claim **1**, wherein the conductive pin element is press-fit at least partially within the opening proximate the second surface region such that the plurality of windings are at least partially compressed within the opening between the engagement surface proximate the first surface region and the engagement surface of the conductive pin element.

6. The adapter apparatus of claim **1**, wherein the spring sleeve contact is mounted within the opening such that the first winding section is configured to allow a male pin to be inserted therethrough and such that the windings of the second winding section having a smaller diameter contact the male pin inserted therein, and further wherein the second winding section is in contact with the conductive pin element.

7. The adapter apparatus of claim **1**, wherein the engagement surface of the conductive pin element is part of a first end portion of the conductive pin element that further comprises an elongate element configured to extend within the center of the second winding section, and further wherein the conductive pin element comprises a second end portion opposite the first end portion configured for attachment to corresponding pads of a target board.

8. An adapter apparatus comprising a plurality of conductive sleeve spring contacts, wherein each sleeve spring contact comprises a conductive sleeve spring extending between a first spring end and a second spring end along a spring axis, wherein each sleeve spring comprises a first winding section comprising a plurality of windings about the spring axis terminating in the first spring end and a second winding section comprising a plurality of windings terminating in the second spring end, wherein the plurality of windings of the second winding section of the sleeve spring comprise at least three or more windings in contact with adjacent windings and at least one or more windings that have a smaller diameter than other windings of the second winding section for making contact with a male pin when the male pin is inserted along the axis of the sleeve spring, and further wherein the first winding section of the sleeve spring comprises a plurality of windings that are not in contact with adjacent windings, wherein each of the plurality of conductive sleeve spring contacts are mounted in a corresponding opening of a plurality of openings defined in a substrate, wherein the substrate comprises a first surface region and a second surface region opposite the first surface region, wherein each of the openings is defined through the substrate from the first surface region to the second surface region, wherein an engagement surface defines at least a portion of the opening proximate the first surface region to engage a first spring end of a sleeve spring mounted within the opening, and further wherein the adapter apparatus comprises a conductive pin element mounted at least partially within the opening proximate the second surface region, wherein the conductive pin element comprises an engagement surface to engage the second spring end of the sleeve spring mounted within the opening, and further wherein the conductive pin element is mounted at least partially within the opening proximate the second surface region using a curable material such that the sleeve spring is at least partially compressed within the opening between the engagement surface proximate the first surface region and the engagement surface of the conductive pin element.

9. The adapter apparatus of claim **8**, wherein each of the conductive sleeve springs is mounted within the opening in a compressed state by a conductive pin element, wherein the conductive pin element comprises a first end portion for contact with the second spring end terminating the second winding section and a second end portion opposite the first end portion configured for attachment to a corresponding pad of a target board.

10. The adapter apparatus of claim **8**, wherein the conductive pin element is press-fit at least partially within the opening proximate the second surface region such that the sleeve spring is at least partially compressed within the opening between the engagement surface proximate the first surface region and the engagement surface of the conductive pin element.

11. A method for use in forming an adapter apparatus, wherein the method comprises:

- providing a substrate including a plurality of openings defined therethrough, wherein the substrate comprises a first surface region and a second surface region opposite the first surface region, wherein each of the openings is defined through the substrate from the first surface region to the second surface region, and further wherein an engagement surface defines at least a portion of the opening proximate the first surface region;
- inserting a conductive sleeve spring into each of the plurality of openings at the second surface region, wherein each conductive sleeve spring extends between a first spring end and a second spring end along a spring axis, wherein each sleeve spring comprises a first winding section comprising a plurality of windings about the spring axis terminating in the first spring end and a second winding section comprising a plurality of windings terminating in the second spring end, wherein the plurality of windings of the second winding section of the sleeve spring comprises at least three or more windings in contact with adjacent windings and at least one or more windings that have a smaller diameter than other windings of the second winding section for making contact with a male pin when the male pin is inserted along the axis of the sleeve spring, and further wherein the first winding section of the sleeve spring comprises a plurality of windings that are not in contact with adjacent windings; and
- positioning a conductive pin element at least partially within the opening proximate the second surface region to compress the sleeve spring within the opening, wherein the conductive pin element comprises an engagement surface, and further wherein positioning the conductive pin element at least partially within the opening proximate the second surface region to compress the sleeve spring within the opening comprises mounting the conductive pin element at least partially within the opening using a curable material and compressing the

sleeve spring between the engagement surface proximate the first surface region and the engagement surface of the conductive pin element.

12. The method of claim **11**, wherein positioning the conductive pin element at least partially within the opening proximate the second surface region to compress the sleeve spring within the opening comprises press-fitting the conductive pin element at least partially within the opening.

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