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(54) **SOCKETS FOR "SPRINGED" SEMICONDUCTOR DEVICES**

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(60) Provisional application No. 60/051,365, filed on Jun. 30, 1997.

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

(57) **ABSTRACT**

Temporary connections to spring contact elements extending from an electronic component such as a semiconductor device are made by urging the electronic component, consequently the ends of the spring contact elements, vertically against terminals of an interconnection substrate, or by horizontally urging terminals of an interconnection substrate against end portions of the spring contact elements. A variety of terminal configurations are disclosed.

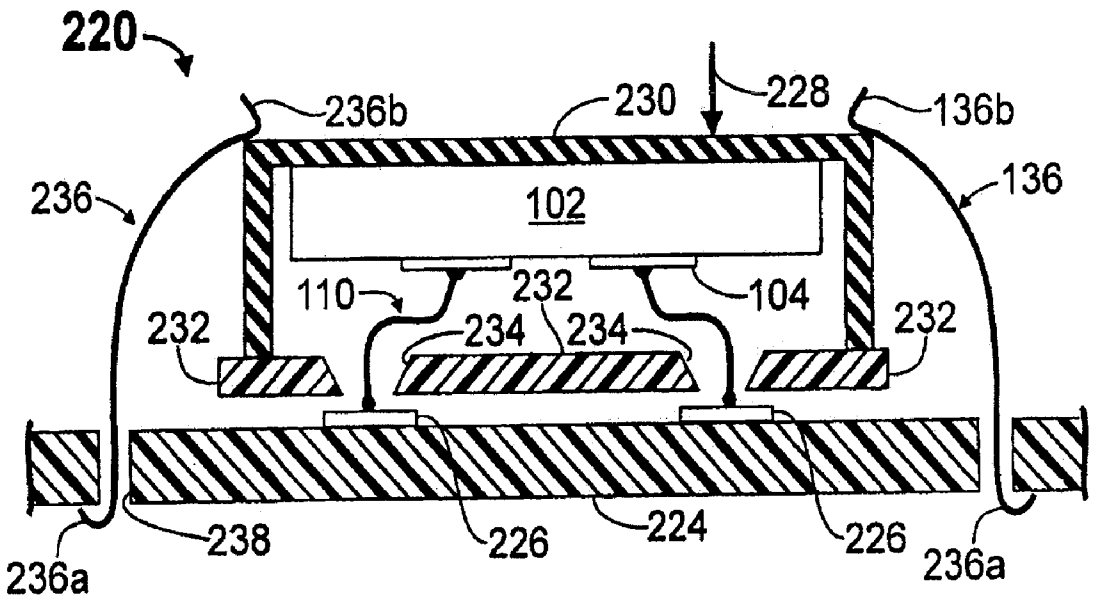


Figure 1

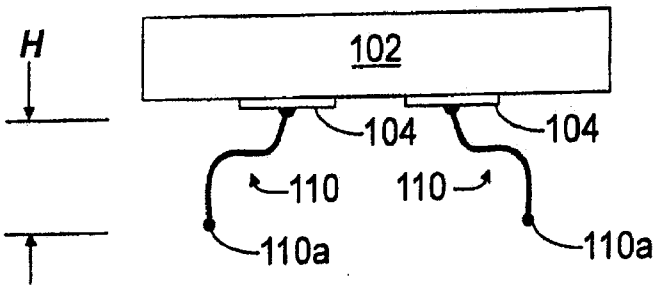


Figure 2

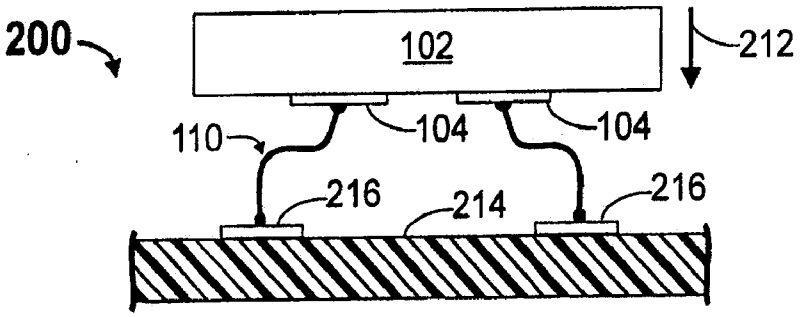


Figure 2A

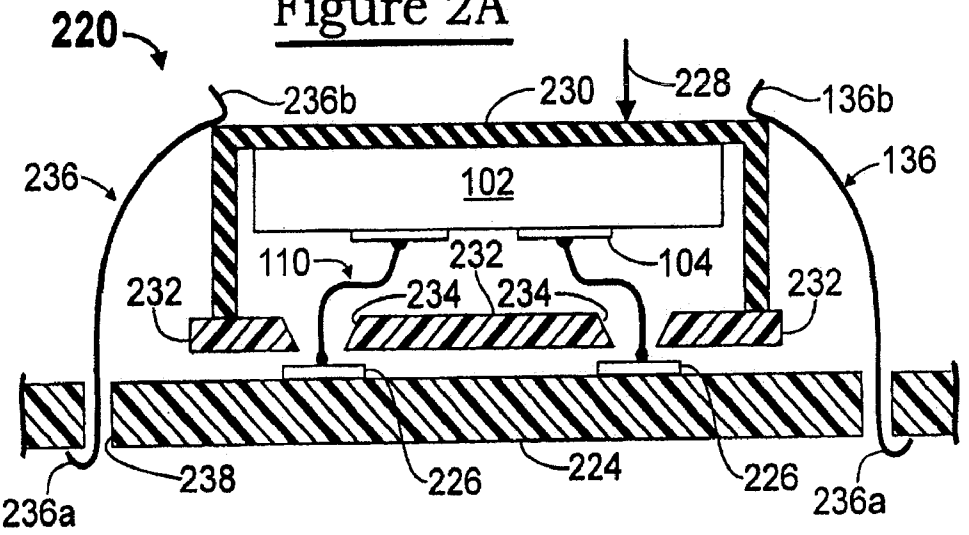


Figure 3

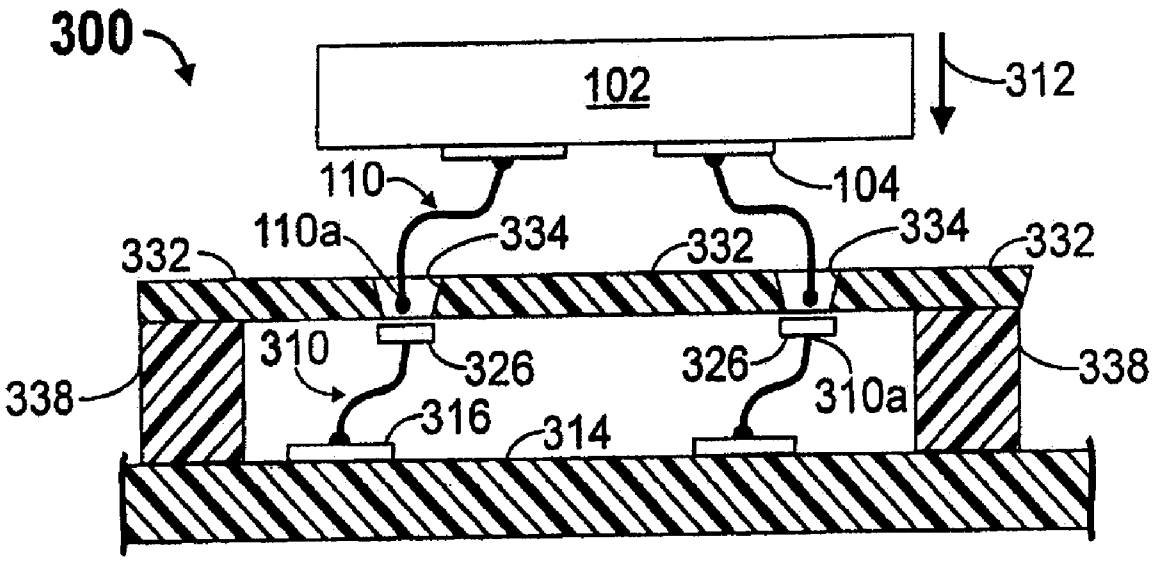


Figure 4

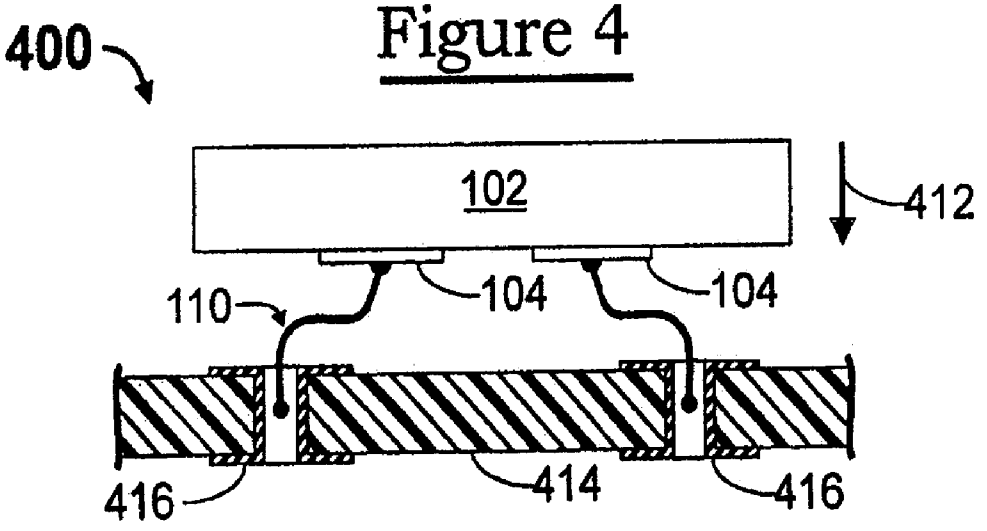


Figure 5A

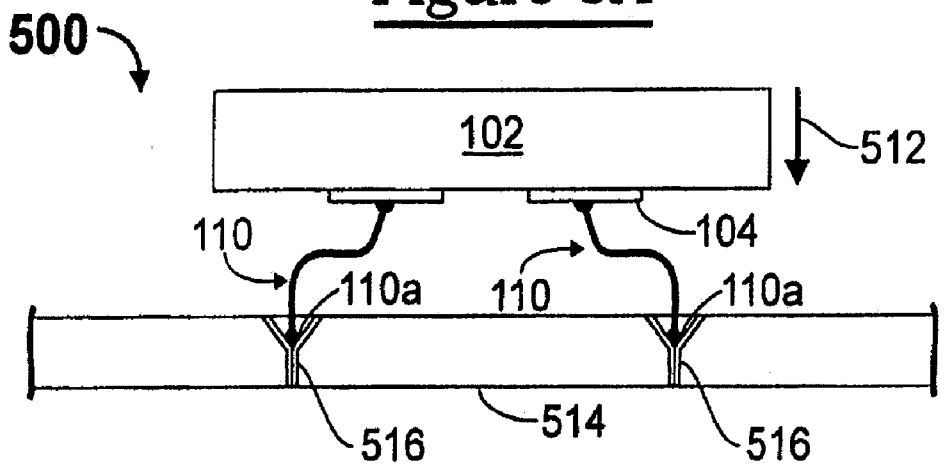


Figure 5B

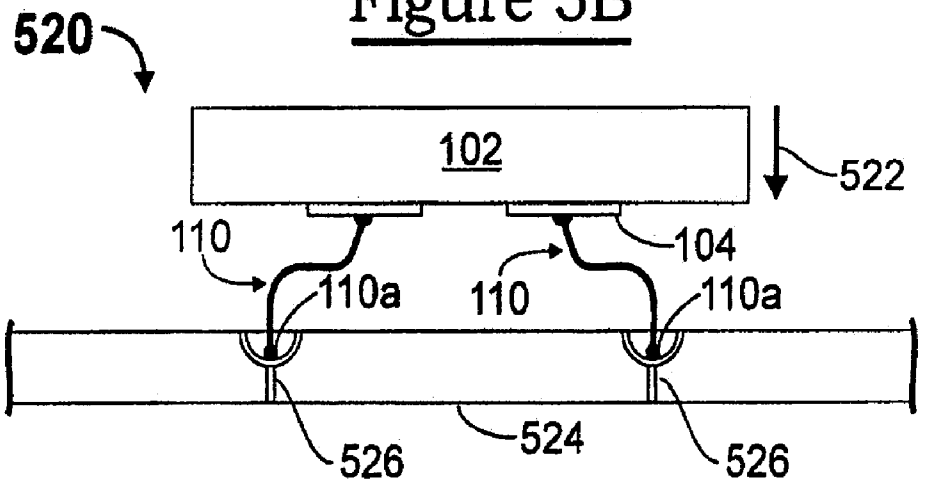


Figure 5C

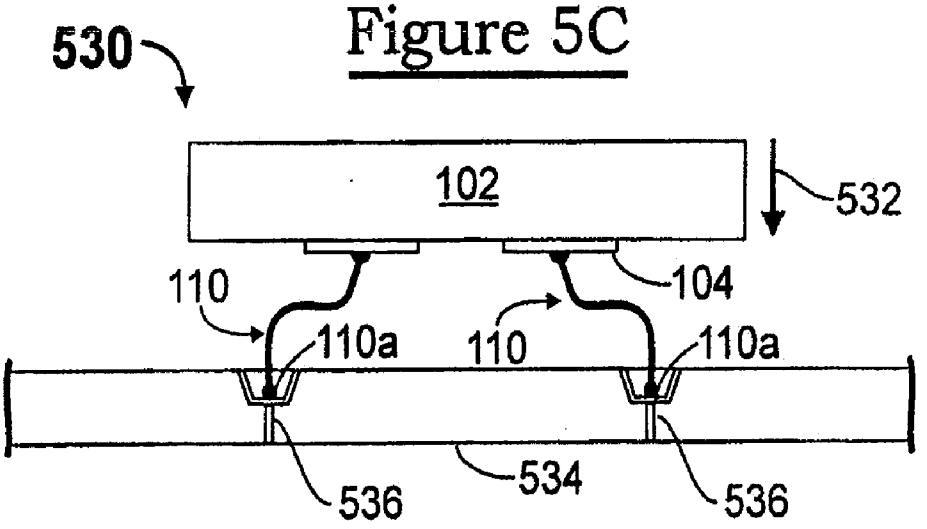


Figure 6A

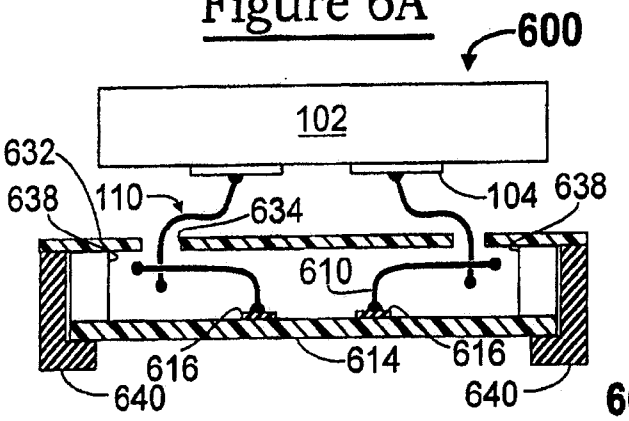


Figure 6B

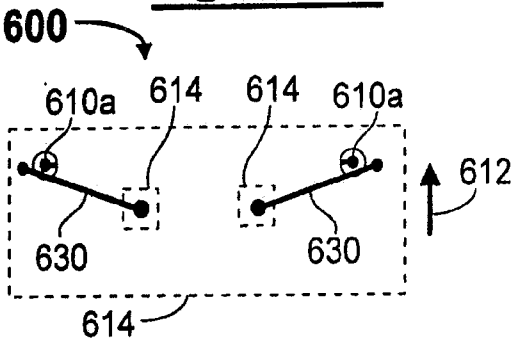


Figure 7A

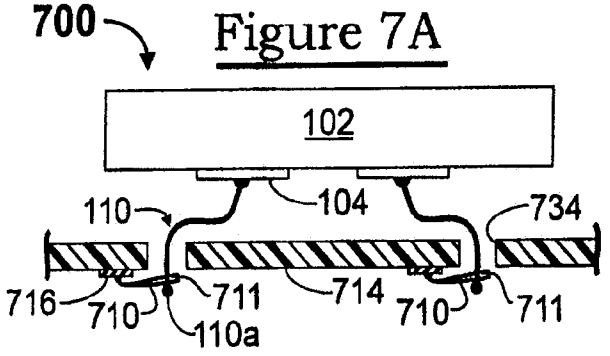


Figure 7B

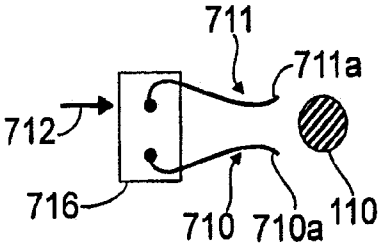


Figure 7C

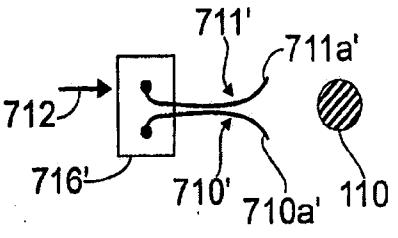


Figure 8

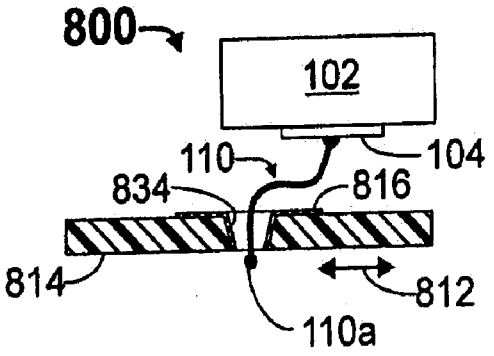


Figure 9A

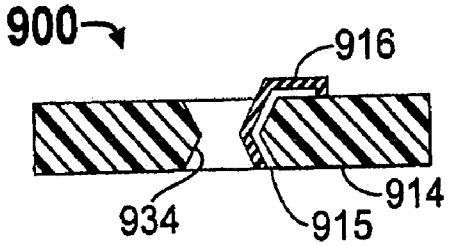
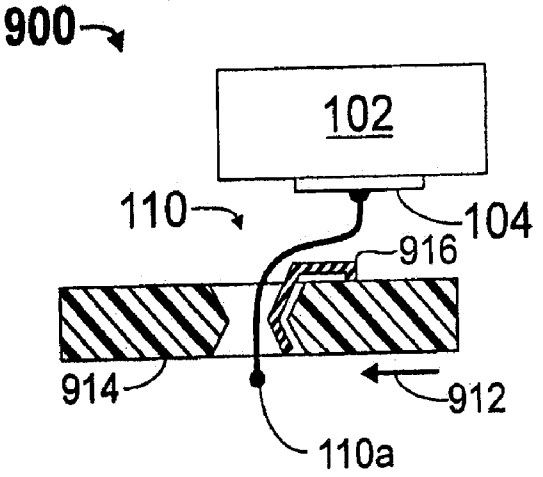


Figure 9B



SOCKETS FOR "SPRINGED" SEMICONDUCTOR DEVICES

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This is a continuation of commonly-owned, copending U.S. Provisional Patent Application No. 60/051,365 filed Jun. 30, 1997.

TECHNICAL FIELD OF THE INVENTION

[0002] The invention relates to making interconnections between electronic components, especially microelectronic components and, more particularly, to interconnection elements (contact structures) exhibiting resiliency (springiness), and methods of making same.

BACKGROUND OF THE INVENTION

[0003] Commonly-owned U.S. patent application Ser. No. 08/152,812 filed 16 Nov. 93 (now U.S. Pat. No. 4,576,211, issued 19 Dec. 95), and its counterpart commonly-owned copending "divisional" U.S. patent applications Ser. No. 08/457,479 filed 01 Jun. 95 (status: pending) and Ser. No. 08/570,230 filed 11 Dec. 95 (status: pending), all by KHANDROS, disclose methods for making resilient interconnection elements for microelectronics applications involving mounting an end of a flexible elongate core element (e.g., wire "stem" or "skeleton") to a terminal on an electronic component, coating the flexible core element and adjacent surface of the terminal with a "shell" of one or more materials having a predetermined combination of thickness, yield strength and elastic modulus to ensure predetermined force-to-deflection characteristics of the resulting spring contacts. Exemplary materials for the core element include gold. Exemplary materials for the coating include nickel and its alloys. The resulting spring contact element is suitably used to effect pressure, or demountable, connections between two or more electronic components, including semiconductor devices.

[0004] Commonly-owned, copending U.S. patent application Ser. No. 08/340,144 filed 15 Nov. 94 and its corresponding PCT Patent Application No. PCT/US94/13373 filed 16 Nov. 94 (WO95/14314, published 26 May 95), both by KHANDROS and MATHIEU, disclose a number of applications for the aforementioned spring contact elements, and also discloses techniques for fabricating contact pads (contact tip structures) at the ends of the spring contact elements.

[0005] Commonly-owned, copending U.S. patent application Ser. No. 08/452,255 filed 26 May 95 and its corresponding PCT Patent Application No. PCT/US95/14909 filed 13 Nov. 95 (WO96/17278, published 06 Jun. 96), both by ELDRIDGE, GRUBE, KHANDROS and MATHIEU, disclose additional techniques and metallurgies for fabricating spring contact elements as composite interconnection structures and for fabricating and mounting contact tip structures to the free ends (tips) of the composite interconnection elements.

[0006] Commonly-owned, copending U.S. patent application Ser. No. 08/558,332 filed 15 Nov. 95 by ELDRIDGE, GRUBE, KHANDROS and MATHIEU, and its corresponding PCT Patent Application No. US95/14885 filed 15 Nov. 95 by ELDRIDGE, GRUBE, KHANDROS and MATHIEU disclose methods of fabricating resilient contact structures which are particularly well-suited to fabricating spring contact elements directly on semiconductor devices. As used herein, a semiconductor device having spring contact elements mounted thereto is termed a "springed semiconductor device".

[0007] Commonly-owned, copending U.S. Provisional Patent Application No. 60/024,555 filed 26 Aug. 96, by ELDRIDGE, KHANDROS and MATHIEU, and PCT Patent Application No. US97/08606 filed 15 May 97 by DOZIER, ELDRIDGE, KHANDROS, MATHIEU and TAYLOR disclose additional contact tip structure metallurgies and structures.

[0008] The present invention addresses and is particularly well-suited to making interconnections to modern microelectronic devices having their terminals (bond pads) disposed at a fine-pitch. As used herein, the term "fine-pitch" refers to microelectronic devices that have their terminals disposed at a spacing of less than 5 mils, such as 2.5 mils or 65 μm. As will be evident from the description that follows, this is preferably achieved by taking advantage of the close tolerances that readily can be realized by using lithographic rather than mechanical techniques to fabricate the contact elements.

BRIEF DESCRIPTION (SUMMARY) OF THE INVENTION

[0009] As mentioned above, a semiconductor device having spring contact elements mounted thereto is termed a "springed semiconductor device". Such a device may be interconnected to an interconnection substrate in one of two main ways. It may be "permanently" connected such as by soldering the free ends of the spring contact elements to corresponding terminals on an interconnection substrate such as a printed circuit board. Alternatively, it may be "temporarily" connected to the terminals simply by urging the springed semiconductor device against the interconnection substrate so that a pressure connection is made between the free ends of the spring contact elements and the terminals. Another way of looking at such temporary pressure connections is that the springed semiconductor device is "self-socketing".

[0010] The ability to remove a springed semiconductor device from its temporary pressure connection with an interconnection substrate is certainly useful in the context of replacing or upgrading the springed semiconductor device. In this context, it is important that the pressure connections be robust, and capable of withstanding the wear and tear associated with normal operations. Generally, a certain minimum contact force is desired to effect reliable pressure contact to electronic components (e.g., to terminals on electronic components). For example, a contact (load) force of approximately 15 grams (including as little as 2 grams or less and as much as 150 grams or more, per contact) may be desired to ensure that a reliable electrical connection is made to a terminal of an electronic component which may be contaminated with films on its surface, or which has corrosion or oxidation products on its surface. The minimum contact force required of each spring contact element demands either that the yield strength of the spring material or that the size of the spring element are increased. As a

general proposition, the higher the yield strength of a material, the more difficult it will be to work with (e.g., punch, bend, etc.). And the desire to make springs smaller essentially rules out making them larger in cross-section.

[0011] A more fundamental object is achieved simply by making transient (very temporary) connections to a springed semiconductor device. And that is, the ability to test the springed semiconductor device prior to temporarily or permanently mounting it to an interconnection substrate of a system to (1), if necessary, burn-in the springed semiconductor device and (2) to ascertain whether the springed semiconductor device is measuring up to its specifications. As a general proposition, this can be accomplished by making "transient" pressure connections with the spring contact elements with relaxed constraints on contact force and the like. The making of such transient connections to springed semiconductor devices is the focus of the present invention. The present invention discloses a number of techniques for socketing (making transient pressure connections) to springed semiconductor devices.

[0012] According to the invention, methods and apparatuses for effecting a temporary connection to a portion of an elongate spring contact element mounted to and extending from an electronic component are provided.

[0013] In one embodiment, an interconnection substrate has a terminal which is a plated through hole. The spring contact element is inserted through the through hole so that a portion of the spring contact element is within the through hole.

[0014] Additional methods, apparatuses and embodiments thereof are disclosed herein.

[0015] Other objects, features and advantages of the invention will become apparent in light of the following description thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] Reference will be made in detail to preferred embodiments of the invention, examples of which are illustrated in the accompanying drawings. The drawings are intended to be illustrative, not limiting. Although the invention will be described in the context of these preferred embodiments, it should be understood that it is not intended to limit the spirit and scope of the invention to these particular embodiments. Certain elements in selected ones of the drawings are illustrated not-to-scale, for illustrative clarity. Often, similar elements throughout the drawings are referred to by similar references numerals. For example, the element **199** may be similar in many respects to the element **299** in another figure. Also, often, similar elements are referred to with similar numbers in a single drawing. For example, a plurality of elements **199** may be referred to as **199***a*, **199***b*, **199***c*, etc.

[0017] **FIG. 1** is a side cross-sectional view of a "springed" semiconductor device, according to the invention.

[0018] In the following figures, a springed semiconductor device is shown with spring contact elements which are mounted thereto and extend therefrom contacting corresponding terminals of an interconnection substrate. In some of the figures, the spring contact elements are shown contacting the terminals. Other of the figures are slightly exploded for illustrative clarity, showing the spring contact elements nearly in contact with the terminals.

[0019] **FIG. 2** is a side cross-sectional view of a "springed" semiconductor device being urged against an interconnection substrate such as a printed circuit board (PCB), according to the invention.

[0020] **FIG. 2A** is a side cross-sectional view of another technique of urging a springed semiconductor device against an interconnection substrate, according to the invention.

[0021] **FIG. 3** is a side cross-sectional view of another technique of urging a springed semiconductor device into contact with terminals of an interconnection substrate, according to the invention.

[0022] **FIG. 4** is a side cross-sectional view of another technique of connecting a springed semiconductor device to terminals of an interconnection substrate, according to the invention.

[0023] **FIG. 5A** is a side cross-sectional view of a technique of urging a springed semiconductor device into contact with concave terminals of an interconnection substrate, according to the invention.

[0024] **FIG. 5B** is a side cross-sectional view of another technique of urging a springed semiconductor device into contact with concave terminals of an interconnection substrate, according to the invention.

[0025] **FIG. 5C** is a side cross-sectional view of another technique of urging a springed semiconductor device into contact with concave terminals of an interconnection substrate, according to the invention.

[0026] **FIG. 6A** is a side cross-sectional view of another technique of horizontally contacting spring contact elements extending from a springed semiconductor device with resilient contact structures extending from terminals of an interconnection substrate, according to the invention.

[0027] **FIG. 6B** is a bottom plan view of the apparatus of **FIG. 6A**, according to the invention.

[0028] **FIG. 7A** is a side cross-sectional view of another technique of horizontally contacting spring contact elements extending from a springed semiconductor device with pairs of resilient contact structures extending from terminals of an interconnection substrate, according to the invention.

[0029] **FIG. 7B** is a bottom plan view of the apparatus of **FIG. 7A**, according to the invention.

[0030] **FIG. 7C** is a bottom plan view of an alternate embodiment of the apparatus of **FIG. 7A**, according to the invention.

[0031] **FIG. 8** is a side cross-sectional view of another technique of horizontally contacting spring contact elements extending from a springed semiconductor device with terminals of an interconnection substrate, according to the invention.

[0032] **FIGS. 9A and 9B** are side cross-sectional views of another technique of horizontally contacting spring contact elements extending from a springed semiconductor device with terminals of an interconnection substrate, according to the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0033] **FIG. 1** illustrates a "springed" semiconductor device **102**, which is an electronic component having a plurality (two of many shown) of free-standing elongate microspring spring contact structures **110** mounted to and extending from a corresponding plurality (two of many shown) of terminals **104** on a surface thereof. Each spring contact element **110** extends laterally parallel to the surface of the component **102** (in the "x" and "y" axes, and extends to a height "H" in the z-axis above the surface of the component **102**.

[0034] As discussed in a number of the aforementioned patents and patent applications, the springed semiconductor device **102** can be connected to another electronic component such as a printed circuit board (PCB) or other suitable interconnection substrate simply by urging the free ends (tips) **110***a* of the spring contact elements **110** against corresponding terminals (not shown) on the PCB (not shown). Alteratively, the free ends (tips) of the spring contact elements **110** can be soldered to the terminals of the PCB or interconnection substrate.

[0035] **FIG. 2** illustrates a technique **200** wherein the "springed" semiconductor device **102** is urged (in the direction of the arrow **212**) against an interconnection substrate such as a printed circuit board (PCB) **214** so that the tips **110***a* come into pressure contact with a corresponding plurality (two of many shown) of terminals **216** on the PCB **214** to establish a pressure connection therewith. As mentioned above, the tips **110***a* of the spring contact elements **110** can also be soldered to the terminals **216** of the PCB **214**. The present invention, however, is principally directed to making temporary connections with the spring contact elements (**110**) of springed semiconductor devices (**102**).

[0036] **FIG. 2**, and the figures that follow, are illustrative of making temporary pressure connections to a springed semiconductor device such as for testing the semiconductor device. In this context, the semiconductor device is termed a "device under test" (DUT). In some of the figures, such as in **FIG. 2**, the temporary pressure connection is made in the z-axis, by applying "vertical" pressure to the tip (**110***a*) of the spring contact element (**110**) in a direction which is perpendicular to the surface of the electronic component **102**. In other of the figures, such as in **FIG. 6A**, the temporary pressure connection is made in the x or y axes, by applying "horizontal" pressure to a midportion of the spring contact element (**110**) in a direction which is parallel to the surface of the electronic component **102**.

[0037] **FIG. 2A** illustrates another technique **220** for making a vertical temporary pressure connection with spring contact elements **110** of a springed semiconductor device (DUT) **102**. In a manner similar to that of the technique illustrated in **FIG. 2**, the tips **110***a* of the spring contact elements **110** make pressure connections (contact) with terminals **226** (compare **216**) of a PCB **224** (compare **214**), as illustrated by the arrow **228** (compare **212**). In this example, the DUT **102** is housed within a metal cap (housing) **230** which is a five-sided box such that the back side (top, as viewed) of the DUT is against the bottom surface of the housing **230**. The open (bottom, as viewed) end of the housing **230** is covered by a rigid planar member (substrate) **232** which has a plurality (two of many shown) of guide holes **234** aligned with the tips **110***a* of the spring contact elements **110** which extend therethrough. For example, for spring contact elements **110** having a height "H" of 50 mils, the spring contact elements **110** extend 5 mils beyond the external (bottom, as viewed) surface of the rigid planar substrate **232**.

[0038] The rigid planar substrate **232** is suitably formed of silicon and the guide holes are suitably tapered with their wide ends facing the DUT **102** and the interior of the housing **230**, and is suitably formed of a silicon wafer using conventional semiconductor micromachining techniques. As illustrated, the rigid planar substrate **232** is sized to extend slightly, such as 100-250 mils beyond the four (two visible in the figure) sidewalls of the housing **230**, to completely cover the open (bottom, as viewed) end of the housing **230**. In this manner, the DUT **102** and a major portion of each spring contact element **110** are protected from inadvertent mechanical damage, such as from handling this springed semiconductor device "subassembly" (**102**, **110**, **232**).

[0039] As illustrated in **FIG. 2A**, the subassembly of the DUT **102** within the housing **230** is held against the front (top, as viewed) surface of the PCB **224** by suitable mechanical means, such as spring clips **236** having two ends, one end **236***a* extending into or through corresponding holes **238** in the PCB **224**, the other end **236***b* extending over the external bottom (top, as viewed) surface of the housing **230**. In this manner, a reliable desired amount of pressure can be effected between the spring contact elements **110** and corresponding terminals **226** of the PCB **224**. Such an arrangement is suitable for testing (transient connection) or for more permanent demountable mounting of the subassembly (102/230) to the PCB.

[0040] In summary, there has been described in **FIGS. 2 and 2**A a method of effecting temporary connections to free ends (tips) of elongate spring contact elements mounted to and extending from an electronic component such as a semiconductor device by:

[0041] urging the springed semiconductor device (DUT) against an interconnection substrate (e.g., PCB) so that the tips of the spring contact elements vertically contact corresponding terminals on the PCB.

Another Vertical Technique

[0042] Commonly-owned, copending PCT Patent Application No. US95/14842 filed 13 Nov. 95 by Dozier, Eldridge, Grube, Khandros and Mathieu [C-5-PCT] discloses methods of removably mounting electronic components to a circuit board (interconnection substrate) by providing a socket element with solder contacts on one side thereof and with elongate free-standing spring contact elements on another side thereof, particularly for making pressure connections to corresponding balls and lands of ball grid array (BGA) and land grid array (LGA) electronic components.

[0043] **FIG. 3** illustrates another technique **300** of making vertical pressure connections to tips of spring contact elements **110** of a springed semiconductor device (DUT) **102**. Whereas in the techniques described with respect to **FIGS. 2 and 2**A the interconnection substrate (**214**, **224**) simply had terminals against which the tips (**110***a*) of the spring contact elements (**110**) were pressed, in this technique, the tips **110***a* of the spring contact elements **110** are pressed against terminals **326** (compare **216**) which are disposed at

and joined to the free ends **310***a* of free standing resilient contact structures **310** (compare **110**) which are mounted to and extend from corresponding terminals **316** (compare **216**) of an interconnection substrate **314** (compare **214**). In this manner, the terminals **326** are yielding in the z-axis. The DUT **102** is moved in the direction indicated by the arrow **312** (compare **212**) to effect the connection(s).

[**0044**] The terminals **326** of the resilient contact structures **310** are formed in any suitable manner, such as has been described with respect to joining prefabricated contact tip structures to free ends of elongate resilient contact structures described, for example, in commonly-owned PCT Patent Application Nos. US96/08107 filed 24 May 96 by Eldridge, Khandros and Mathieu [C-14-PCT] and US97/08606 filed 15 May 97 by Dozier, Eldridge, Khandros, Mathieu and Taylor [C-17-PCT], and may be provided with any suitable metallurgy and topology (surface flatness and texture) to optimize pressure connections being made between the terminals **326** and the ends **110** of the spring contact elements **110**. The terminals **326** are suitably "pads" having a cross-dimension (e.g., diameter) of 8-10 mils and are joined to the ends of the elongate resilient contact structures **310** which have a smaller cross-dimension (diameter) such as 4-6 mils.

[**0045**] In a manner similar and comparable to that of the housing **230** (see **FIG. 2A**) a rigid planar substrate **332** (compare **232**) is disposed parallel to the surface of the interconnection substrate **314** at a distance from its surface which is sufficient to be just above the terminals **326**, and is provided with holes **334** (compare **234**) therethrough which are aligned with the terminals **326**. The substrate **332** is maintained in this position by suitable spacers **338** which may be a single, rigid, square, rigid ring-like structure which is comparable to the socket body (**332**) of the aforementioned US95/14842 [C-5-PCT]. In a manner similar to that described hereinabove with respect to **FIG. 2A**, the rigid structure **332** is suitably formed of a silicon wafer using conventional semiconductor micromachining techniques so that the holes **334** are tapered, with their wider opening on the exterior (top, as viewed) surface of the rigid substrate **332**.

[**0046**] Suitably dimensioned, the "socket" formed by the interconnection substrate **314**, the resilient contact structures **310** having pads **326** mounted at their ends, and the rigid substrate **332** having holes **334** aligned with the pads **326** can serve as a socket for a ball grid array (BGA) package (not shown) rather than as a socket for a springed semiconductor device **102**.

[**0047**] In this manner, there is provided a test socket for making temporary pressure connections to tips of elongate contact structures extending from a DUT by:

[**0048**] providing a plurality of elongate free-standing resilient contact structures from corresponding terminals on an interconnection substrate, each of said resilient contact structures being provided with "floating" terminals at their free ends for receiving tips of the elongate contact structures extending from the DUT.

Another Technique

[**0049**] **FIG. 4** illustrates another technique **400** of effecting pressure connections to elongate spring contact elements **110** mounted to and extending from a semiconductor device **102**. This technique is neither strictly vertical (as is the case with the techniques described hereinabove) or horizontal (as is the case with the techniques described hereinbelow).

[**0050**] In this technique, end portions (commencing at the ends **110***a* and extending along the spring contact elements **110**) of the spring contact elements **110** are inserted into plated through hole terminals **416** (compare **216**) of an interconnection substrate **414** (compare **214**) such as a printed circuit board. With a suitable, such as "wavy" shape to the end portions of the spring contact elements **110**, a pressure connection may be effected between the spring contact elements **110** and the terminals **416**. The semiconductor device **102** is moved in a direction indicated by the arrow **412** (compare **212**) to effect the connection(s).

[**0051**] This technique of "plugging" the end portions of the spring contact elements **110** into plated through holes is very amenable to subsequently soldering the springed semiconductor device **102** in place on the PCB **414**. The springed semiconductor device **102** could subsequently be removed (e.g., for replacement) simply by heating to melt the solder, cleaning the through holes, and reinserting and soldering into place another springed semiconductor device.

[**0052**] In this manner, there is provided a socketing technique making connections with end portions of elongate contact structures extending from a semiconductor device by:

[**0053**] providing a plurality of terminals which are plated through holes in an interconnection substrate; and

[**0054**] plugging the end portions of the elongate contact structures into the through holes; and

[**0055**] optionally, soldering the elongate contact structures to the terminals.

Another Vertical Technique

[**0056**] **FIGS. 5A, 5B** and **5**C illustrates other techniques **500**, **520** and **530**, respectively, of effecting pressure connections to elongate spring contact elements **110** mounted to and extending from a semiconductor device **102**. This technique effects a vertical pressure connection between concave terminals of an interconnection substrate and the tips **110***a* of the spring contact elements **110** extending from the DUT **102**.

[**0057**] As shown in **FIG. 5A**, the ends **110***a* of the spring contact elements **110**) of the spring contact elements **110** are brought vertically, as indicated by the arrow **512** (compare **212**), into contact with corresponding ones of a plurality (two of many shown) of terminals **516** (compare **216**) of an interconnection substrate **514** (compare **214**). The terminals **516** are concave. In this example, the terminals **516** are formed like plated through holes (compare **416**) that have an upper portion in the form of a cone or pyramid which has its base at an upper (top, as viewed) surface of the interconnection substrate **514** and its apex (point) within the interconnection substrate **514**.

[**0058**] As shown in **FIG. 5B**, the ends **110***a* of the spring contact elements **110**) of the spring contact elements **110** are brought vertically, as indicated by the arrow **522** (compare **212**), into contact with corresponding ones of a plurality (two of many shown) of terminals **526** (compare **216**) of an interconnection substrate **524** (compare **214**). The terminals

526 are concave. In this example, the terminals **526** are formed like plated through holes (compare **416**) that have an upper portion in the form of a hemisphere which has its base at an upper (top, as viewed) surface of the interconnection substrate **524** and its apex within the interconnection substrate **524**.

[**0059**] As shown in **FIG. 5C**, the ends **110***a* of the spring contact elements **110**) of the spring contact elements **110** are brought vertically, as indicated by the arrow **532** (compare **212**), into contact with corresponding ones of a plurality (two of many shown) of terminals **536** (compare **216**) of an interconnection substrate **534** (compare **214**). The terminals **536** are concave; In this example, the terminals **536** are formed like plated through holes (compare **416**) that have an upper portion in the form of a trapezoidal solid which has relatively wider base portion at an upper (top, as viewed) surface of the interconnection substrate **534** and its relatively shorter base portion within the interconnection substrate **534**.

[**0060**] This is comparable in some regard to the aforementioned technique (see **FIG. 4**) of "plugging" the end portions of the spring contact elements **110** into plated through holes, but relies entirely on vertical pressure to effect the desired contact between the DUT **102** and the terminals **516**, **526**, **536** of the interconnection substrates **514**, **524**, **534**, respectively. In each of the examples of **FIGS. 5A, 5B** and **5**C, the tip **110***a* of the spring contact structure **110** enters the concave terminal **516**, **526**, **536** at its widest portion, thus "capturing" the ends **110***a* of the spring contact elements **110** with the terminals.

[**0061**] In this manner, there is provided a socketing technique making connections with end portions of elongate contact structures extending from a semiconductor device by:

[**0062**] providing a plurality of concave terminals on an interconnection substrate, each of the concave terminals having a widest portion at a surface of the interconnection substrate; and pressing the tips of the elongate contact structures into the concave terminals.

A Horizontal Pressure Technique

[**0063**] There have been described hereinabove a number of techniques for effecting temporary pressure connections to elongate spring contact elements (**110**) of a springed semiconductor device (**102**) by applying pressure vertically (normal to the surface of the component **102**) to the tips (**110***a*) of the spring contact elements (**110**). In certain instances, this can cause the spring contact elements (**110**) to become permanently (plastically) deformed in the z-axis. It is thus desirable to provide a technique for making a "z-less" or low insertion force socket for contacting the elongate spring contact elements (**110**) of springed semiconductor devices (**102**). Hence, there are described hereinbelow a number of techniques for making temporary pressure connections to elongate spring contact elements (**110**) of a springed semiconductor device (**102**) by applying pressure horizontally (parallel to the surface of component **102**) to end portions of the spring contact elements (**110**).

[**0064**] **FIGS. 6A and 6B** illustrate a technique **600** for making temporary pressure connections to elongate spring contact elements **110** of a springed semiconductor device (DUT) **102**. The tips **110***a* of the elongate spring contact elements **110** extend through a plurality (two of many shown) of holes **634** (compare **334**) through a rigid substrate **632** which is comparable to the aforementioned rigid substrate **332** in that the rigid substrate **632** formes a protective cover for elongate rigid contact structures **610** (compare **310**) mounted to and extending from terminals **616** (compare **316**) on an interconnection substrate **614** (compare **314**). The interconnection substrate **614** is supported below the rigid substrate **632** by a spacer **638** (compare **338**) such as a square ring. Also, a body portion **640** of the socket has sidewalls which extends from the lower (bottom, as viewed) surface of the rigid substrate, around the periphery of the interconnection substrate **614**, to the bottom surface of the interconnection substrate **614** just within its periphery. The interconnection substrate **614** may be provided with resilient contact structures (not shown) on its bottom (as viewed) surface to make pressure connections to yet another interconnection substrate (not shown) such as a printed circuit board (PCB).

[**0065**] In contrast to the resilient contact structures **310** which are primarily oriented normal to the surface of the interconnection substrate **314** to make vertical pressure connections to the ends **110***a* of the spring contact elements **110**, in this technique the resilient contact structures **610** mounted to and extending from the terminals **616** of the interconnection substrate **614** extend primarily parallel to the surface of the interconnection substrate **614** so as to make horizontal pressure connections to end portions of the spring contact elements **110**. As viewed in **FIG. 6A**, an end portion of each resilient contact structure **630** is positioned to extend horizontally across an end portion of a corresponding one of the spring contact elements **110**. Stated another way, the tip **110***a* of each spring contact element **110** extends beyond the horizontal end portion of a corresponding one of the resilient contact structures **630**. As best viewed in **FIG. 6B**, this ensures that the end portions of the resilient contact structures **630** will resiliently urge against the end portions of the spring contact elements **110** when the interconnection substrate **614** is moved in a direction shown by the arrow **612** (compare **312**) which is parallel to the surfaces of the DUT **102** and the interconnection substrate **614**. In other words, they "criss-cross" one another.

[**0066**] In this manner, a technique is provided for making connections with end portions of elongate contact structures extending from a semiconductor device by:

[**0067**] urging end portions of elongate resilient contact structures mounted to and extending from terminals on an interconnection substrate horizontally against end portions of spring contact elements mounted to and extending from a semiconductor device.

Another Horizontal Pressure Technique

[**0068**] In the previously-described technique, a single resilient contact structure (**610**), the end portion of which is horizontally (parallel to the interconnection substrate) oriented, criss-crosses and contacts an end portion of a single spring contact element (**110**) extending vertically from a semiconductor device (**102**) with a contact force which is horizontal.

[**0069**] **FIGS. 7A, 7B** and **7**C illustrate another horizontal pressure technique **700** wherein a pair of (two) generally parallel spaced-apart resilient contact structures **710** and **711**

(compare **610**) make horizontal contact with an end portion of a spring contact element **110** extending from a springed semiconductor device **102**.

[**0070**] As best viewed in **FIGS. 7 and 7**A, a pair of two spaced-apart resilient contact structures **710** and **711** extend from a single terminal **716** (compare **616**) on a bottom (as viewed) surface of an interconnection substrate **714** across a hole **734** (compare **634**) through the interconnection substrate **714**. An end portion of a corresponding one of the spring contact elements **110** extending from the semiconductor device **102** extends through the hole **734** beyond the resilient contact structures **710** and **711** (i.e., past their z-axis coordinate) at a position which is slightly inward from the ends **710***a* and **711***a* of the resilient contact structures **710** and **711**, respectively.

[**0071**] In the embodiment of **FIG. 7B**, the two resilient contact structures **710** and **711** are spaced apart a distance (e.g., 3 mm) which is less than the thickness or diameter (e.g., 5 mm) of the end portion of the spring contact element **110** being captured (pinched) at the position where they will grab the spring contact element **110** and are shaped as follows. They originate from (are mounted to) the same terminal **716** at a distance (e.g. 5 mm) apart from one another, then curve slightly (e.g., 1 mm) outward (away from one another), then curve back towards one another so as to be spaced less than the diameter of the spring contact element **110** from one another, then curve outwards again to provide a "tapered" entry for the spring contact element **110** to slip past their tips **710** and **711** into the gap between the two generally parallel resilient contact structures **710** and **711** when the terminal **716** (i.e., the interconnection substrate **714**) is moved in the horizontal direction indicated by the arrow **712** (compare **612**).

[**0072**] In the embodiment of **FIG. 7C**, the two resilient contact structures **710'** and **711'** are spaced apart a distance (e.g., 3 mm) which is less than the thickness or diameter (e.g., 5 mm) of the end portion of the spring contact element **110** being captured (pinched) at the position where they will grab the spring contact element **110** and are shaped as follows. They originate from (are mounted to) the same terminal **716'** at a distance (e.g. 5 mm) apart from one another, then curve slightly (e.g., 1 mm) inward (towards from one another), then curve outwards again to provide a "tapered" entry for the spring contact element **110** to slip past their tips **710'** and **711'** into the gap between the two generally parallel resilient contact structures **710'** and **711'** when the terminal **716** (i.e., the interconnection substrate **714**) is moved in the horizontal direction indicated by the arrow **712** (compare **612**).

[**0073**] In this manner, a technique is provided for making connections with end portions of elongate contact structures extending from a semiconductor device by:

[**0074**] capturing an end portion of a spring contact element mounted to and extending from a semiconductor device between end portions of a pair of horizontally spaced-apart elongate resilient contact structures mounted to and extending from a terminal on an interconnection substrate.

Another Horizontal Pressure Technique

[**0075**] In **FIGS. 6A, 6B**, 7A, 7B, 7C, techniques are described for effecting a horizontal pressure connection to an elongate spring contact element **110** extending from an electronic component **102** with one or more resilient contact structures (**610**, **710**, **711**, **710'**, **711'**) extending from terminals (**616**, **716**, **716'**) of an interconnection substrate (**614**, **714**). This is reminiscent of the technique described with respect to **FIG. 3** wherein a vertical pressure connection is made to an elongate spring contact element **110** extending from an electronic component **102** with a resilient contact structures (**310**) extending from a terminal (**316**) of an interconnection substrate (**314**). Both techniques will effect a "soft" pressure connection.

[**0076**] **FIG. 8** illustrates a technique **800** for effecting a "harder" temporary pressure connection to an end portion of an elongate spring contact element **110** (only one shown in this example) extending from an electronic component **102**. In this example, an interconnection substrate **814** (compare **214**, **414**) is provided with a plurality of through holes **834** (compare **234**) which are tapered to have a wider opening to receive the end **110***a* of a spring contact element **110**. The through holes are plated **816** (compare **416**) to provide terminals for contacting the end portions of the spring contact elements **110**. The through holes need only be partially plated on one side, but are shown as being fully plated.

[**0077**] To effect a pressure connection between the terminals **816** and the end portion of the spring contact element **110**, the tip **110***a* of the spring contact element **110** is inserted from one (top, as viewed) side (surface) of the interconnection substrate **110**, through the through hole **834** in the interconnection substrate **814**, so that its tip **110***a* extends out the other (opposite) side of the interconnection substrate **814**. Then, the interconnection substrate **814** is moved horizontally, typically in any direction which is parallel to the surface of the electronic component **802**, as indicated by the arrow **812** (compare **412**) so that the narrower wedge-like portion of the terminal **816** presses into an end portion of the spring contact element **110** near the tip **110***a* thereof. This wedge-like contact concentrates force over a small contact area, thereby ensuring that sufficient contact force is achieved to effect at least a reliable transient pressure connection between the terminals **816** of the interconnection substrate **814** and the spring contact elements **110** of the springed semiconductor device **102**.

[**0078**] In this manner, a technique is provided for making connections with end portions of elongate spring contact elements extending from a semiconductor device by:

[**0079**] providing an interconnection substrate with terminals which are plated through holes which are preferably tapered;

[**0080**] inserting ends of spring contact elements of a springed semiconductor device through the through holes so that end portions of the spring contact elements are within the through holes; and

[**0081**] moving the interconnection substrate horizontally to effect a pressure connection to the end portions of the spring contact elements.

Another Horizontal Pressure Technique

[**0082**] **FIG. 8** illustrated a technique **800** for effecting a relatively "hard" wedge-like horizontal pressure connection to an end portion of an elongate spring contact element **110**

extending from an electronic component **102**. Previously-described techniques, for example that of **FIG. 3**, illustrate a technique **300** for making relatively "soft" vertical connections to the ends of spring contact elements of springed semiconductor devices. **FIGS. 9A and 9B** illustrate a technique **900** for making a relatively "soft" horizontal pressure connection to the ends of spring contact elements of springed semiconductor devices.

[**0083**] **FIG. 9A** illustrates a first step of the technique **900** wherein tapered through holes (one of a plurality shown) **934** (compare **834**) are provided through an interconnection substrate **914** (compare **814**). In this example, the through holes are hourglass shaped, having relatively larger area openings on the two opposite surfaces (top and bottom, as viewed) of the interconnection substrate **914** and a smaller cross-secctional area at a midpoint (thicknesswise) of the interconnection substrate **914**. This is a double-tapered through hole which comes to a point within the body of the interconnection substrate **914**.

[**0084**] A patterned layer **915** of sacrificial metal material such as aluminum is applied to a one (right, as viewed) side of each through hole **934**, such as by plating. The interconnection substrate **914** can be a copper clad PCB to facilitate such plating, and a patterned layer can be plated by first masking the copper.

[**0085**] A layer **916** (compare **816**) of another dissimilar metal material such as nickel is applied over the patterned layer **915**. This layer **916** will conform to the pattern of the underlying layer **915**. Alternatively, the layer **915** is not patterned, and the layer **916** is applied to be patterned (e.g., by first masking the layer **915**).

[**0086**] Next, as illustrated in **FIG. 9B**, the patterned sacrificial layer **915** is removed. This is done using any suitable well-known process such as selective chemical etching, and results in terminals which are double-tapered "fingers" of relatively hard material (**916**) originating from one side of the interconnection substrate **914** and extending in a cantilever manner within the through holes **934**. As illustrated, each of these finger-like terminals (**916**) comes to a point within the body of the interconnection substrate.

[**0087**] To effect a pressure connection between the terminals **916** and the end portion of the spring contact element **110**, the tip **110***a* of the spring contact element **110** is inserted from one (top, as viewed) side (surface) of the interconnection substrate **110**, through the through hole **934** in the interconnection substrate **914**, so that its tip **110***a* extends out the other (opposite) side of the interconnection substrate **914**. Then, the interconnection substrate **914** is moved horizontally, typically in any direction which is parallel to the surface of the electronic component **802**, as indicated by the arrow **912** (compare **812**) so that the point of the finger-like terminal **916** presses into an end portion of the spring contact element **110** near the tip **110***a* thereof. This wedge-like contact concentrates force over a small contact area, thereby ensuring that sufficient contact force is achieved to effect at least a reliable transient pressure connection between the terminals **916** of the interconnection substrate **914** and the spring contact elements **110** of the springed semiconductor device **102**. The material and thickness of the material **916** is selected to be somewhat yielding when the interconnection substrate **914** is urged horizontally against the spring contact elements **110** extending through the through holes.

[**0088**] In this manner, a technique is provided for making connections with end portions of elongate spring contact elements extending from a semiconductor device by:

[**0089**] providing an interconnection substrate with terminals which are elongate finger-like terminals extending in a cantilever-like manner into double-tapered through holes;

[**0090**] inserting ends of spring contact elements of a springed semiconductor device through the through holes so that end portions of the spring contact elements are within the through holes; and

[**0091**] moving the interconnection substrate horizontally to effect a pressure connection between the terminals and the end portions of the spring contact elements.

[**0092**] Although the invention has been illustrated and described in detail in the drawings and foregoing description, the same is to be considered as illustrative and not restrictive in character—it being understood that only preferred embodiments have been shown and described, and that all changes and modifications that come within the spirit of the invention are desired to be protected. Undoubtedly, many other "variations" on the "themes" set forth hereinabove will occur to one having ordinary skill in the art to which the present invention most nearly pertains, and such variations are intended to be within the scope of the invention, as disclosed herein.

1-8. (canceled)

9. An interconnection substrate for receiving an elongate spring contact element, the interconnection substrate comprising:

an interconnection substrate with a terminal which is a plated through hole, the hole designed to receive a corresponding elongate spring contact element and form an electrical connection therewith.

10. The interconnection substrate of claim 9 further comprising an electronic component electrically connected to the interconnection substrate, the electronic component in turn comprising an elongate spring contact element extending away from the electronic component and mating with the terminal of the interconnection substrate to form an electrical connection.

11. The interconnection substrate of claim 9 further comprising a plurality of terminals formed therein, selected ones of which are plated through holes designed to receive corresponding elongate spring contact elements.

12. The interconnection substrate of claim 11 further comprising an electronic component electrically connected to the interconnection substrate, the electronic component in turn comprising a plurality of elongate spring contact elements, selected ones of which extend away from the electronic component and mate with corresponding selected ones of the terminals of the interconnection substrate.

13-17. (canceled)

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