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(54) **PROBE CONTACT SYSTEM USING FLEXIBLE PRINTED CIRCUIT BOARD**

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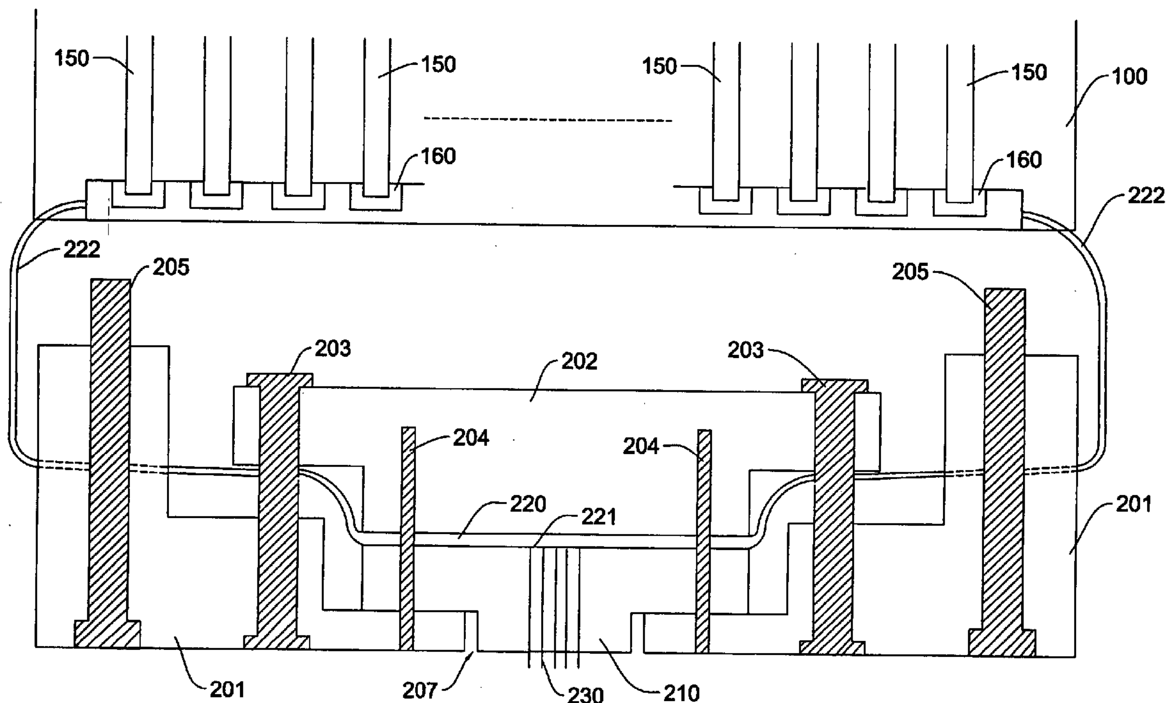
(52) **U.S. Cl.** **324/754**

(57) **ABSTRACT**

A probe contact system for establishing electrical connection with contact targets. The probe contact system is formed of a main frame, a flexible printed circuit board (PCB), a contactor carrier and a plurality of contactors. The flexible PCB has contact pads at a center area thereof and signal lines connected to the contact pads and extended to an end of the flexible PCB. The end of the flexible PCB with the signal lines is connected to a test head of a semiconductor test system. In one aspect, the contactor has a top spring to resiliently contact with the contact pads on the flexible PCB. In another aspect, the probe contact system includes a conductive elastomer sheet between the contactor and the flexible PCB thereby obviating the top spring of the contactor.



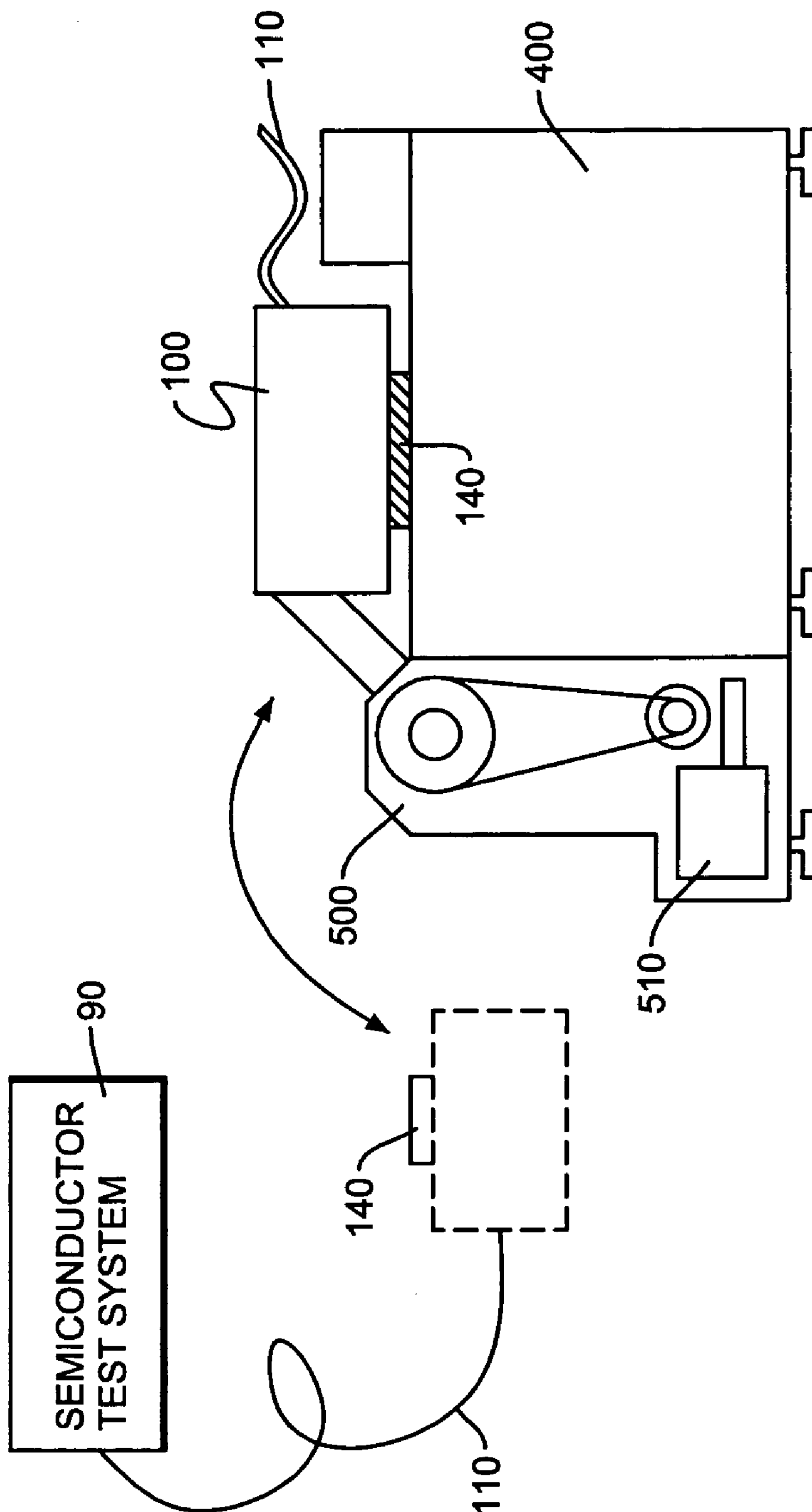


Fig. 1 (Prior Art)

Fig. 2 (Prior Art)

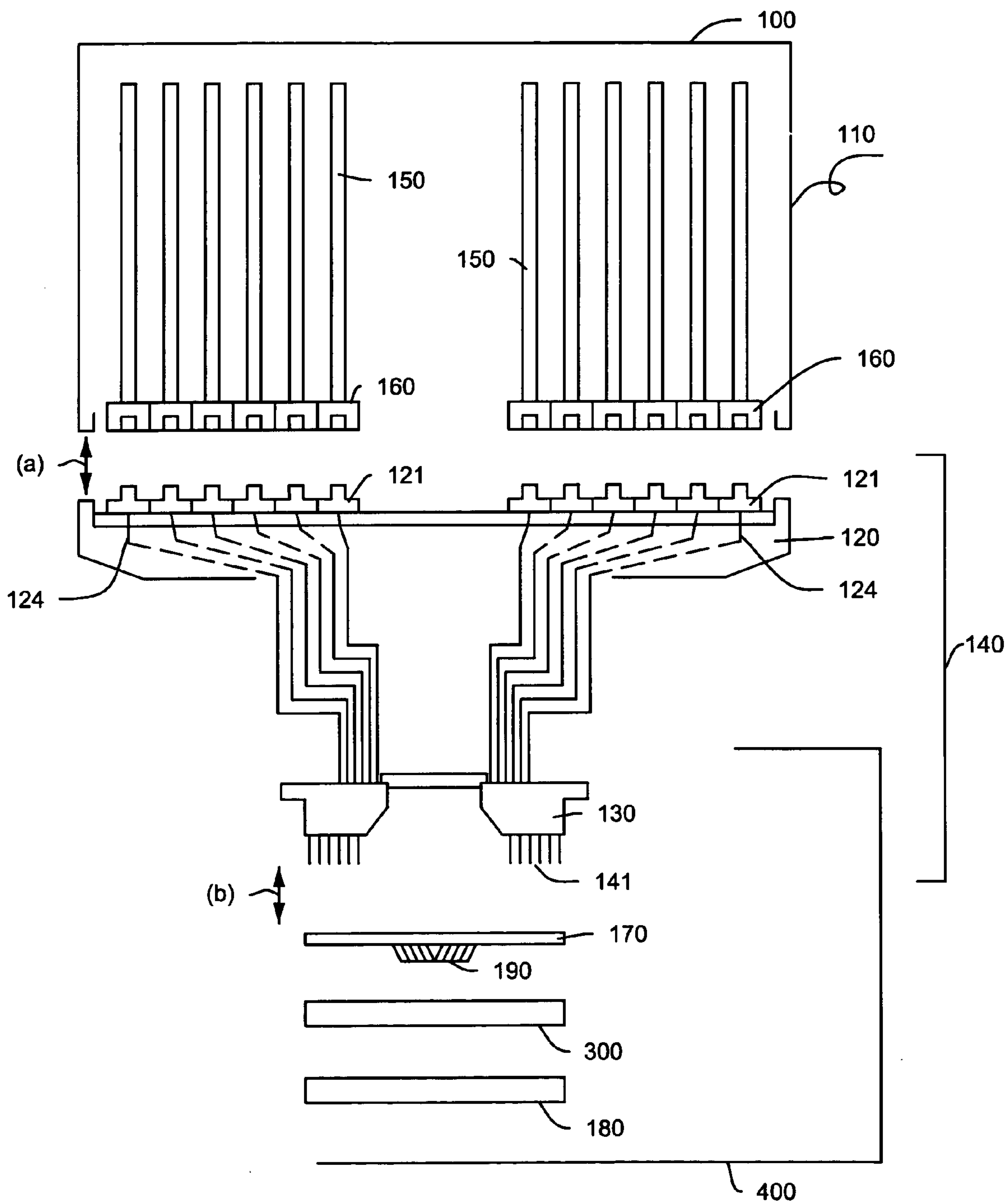
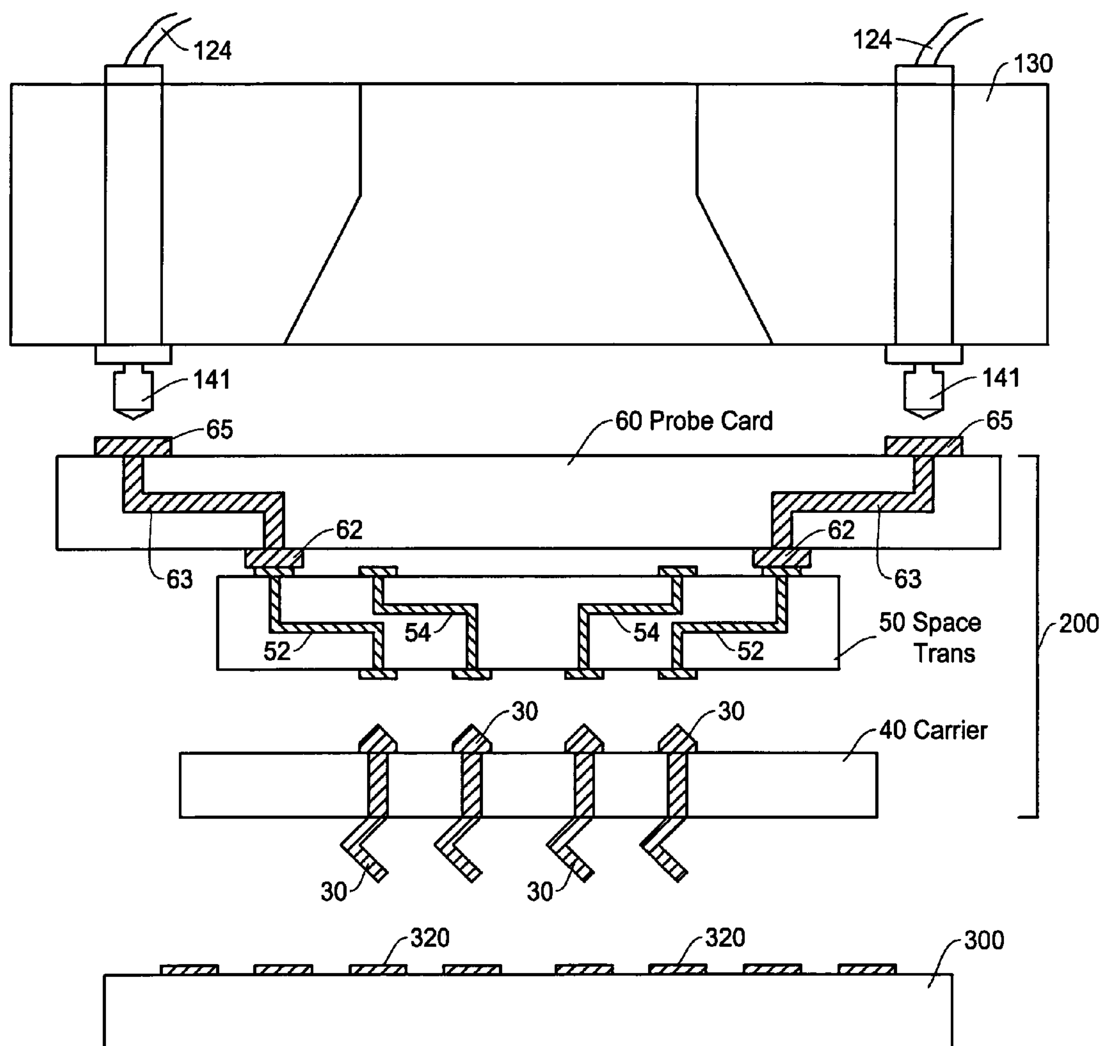


Fig. 3 (Prior Art)



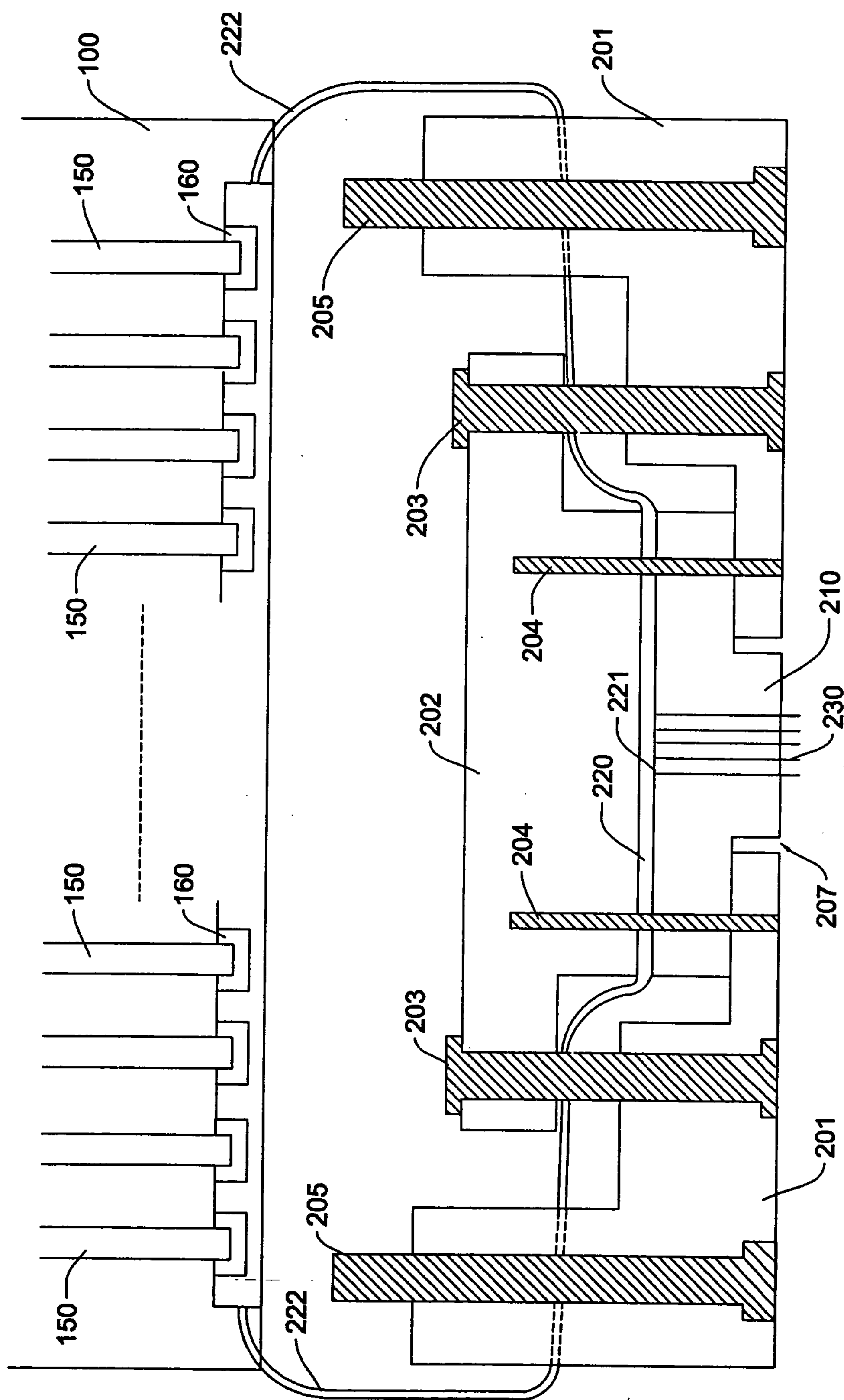


Fig. 4
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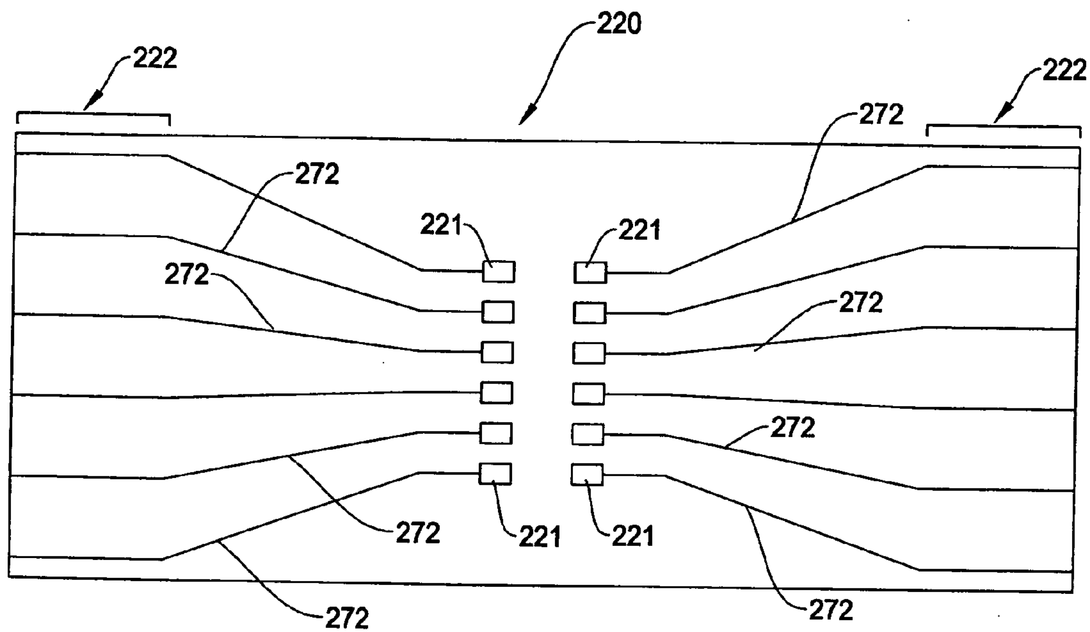
Fig. 5A



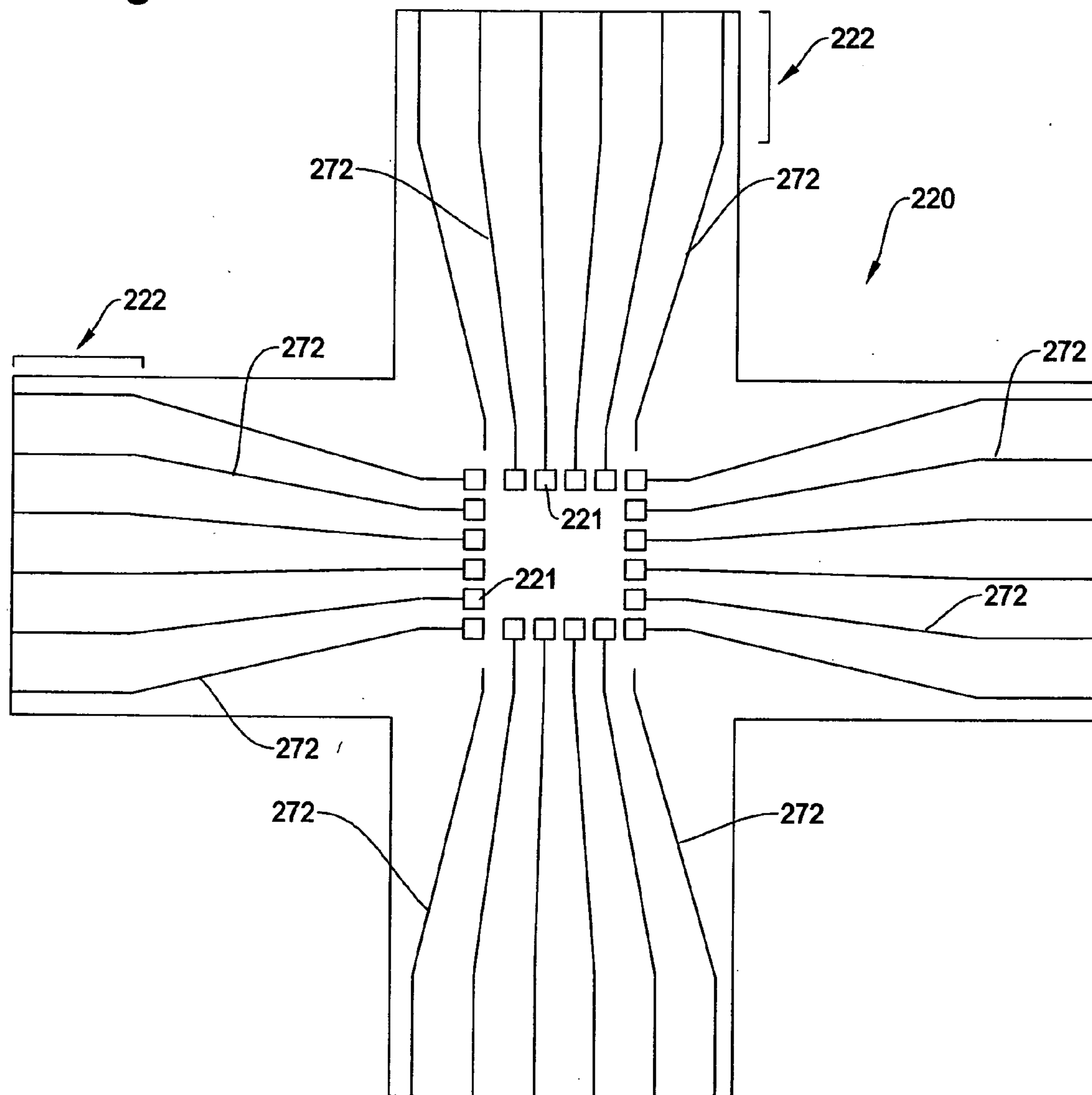


Fig. 5B
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Fig.6

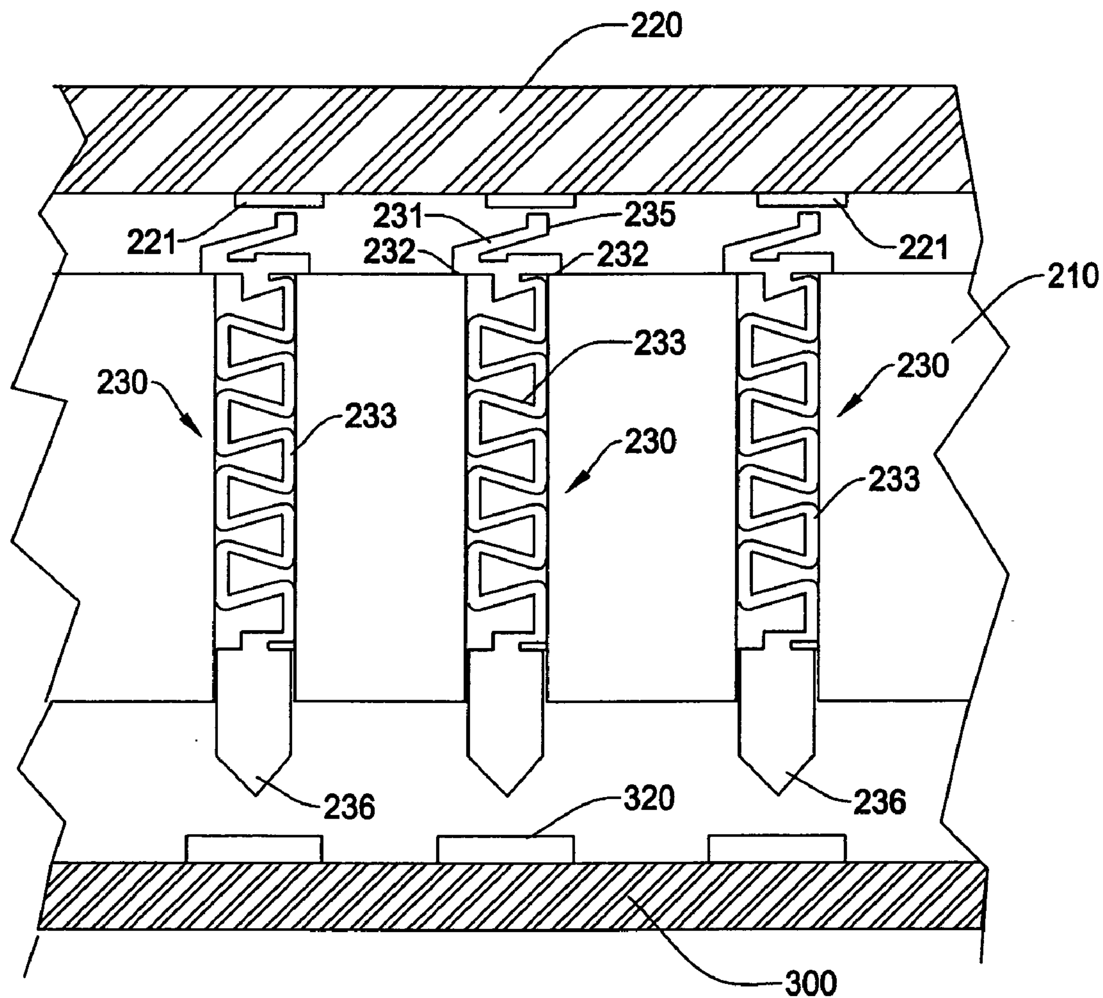


Fig. 7A

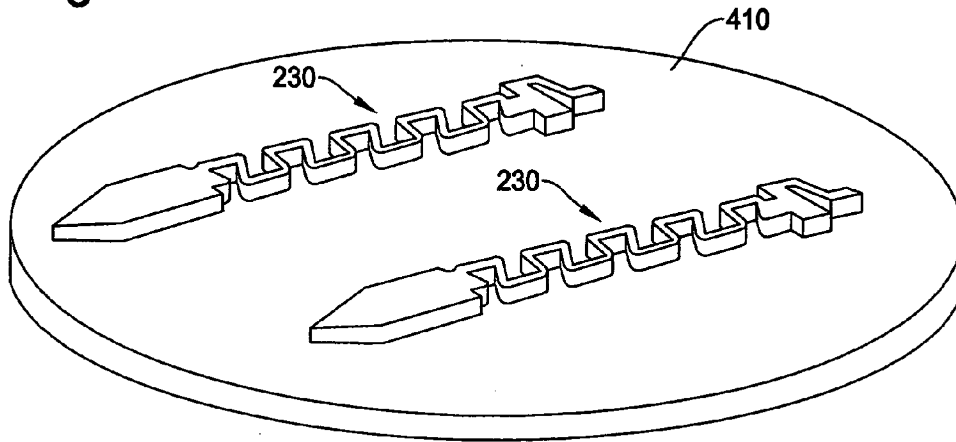


Fig. 7B

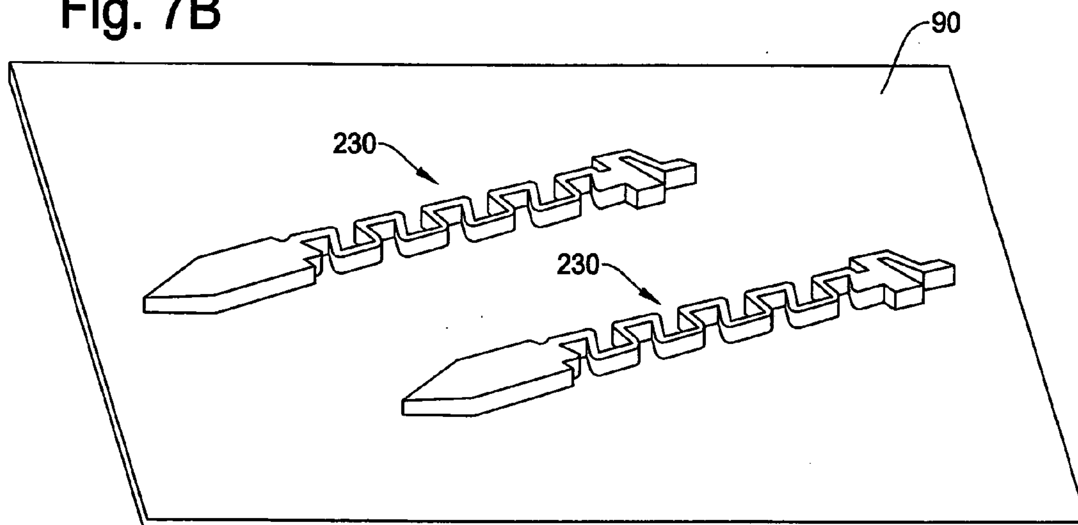


Fig. 8A

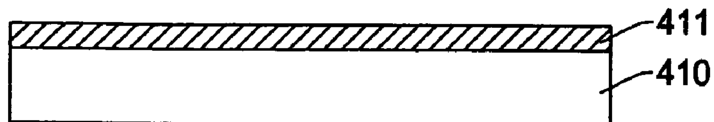


Fig. 8B

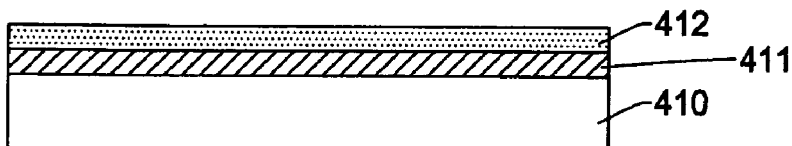
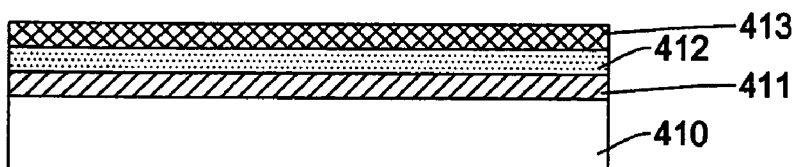


Fig. 8C



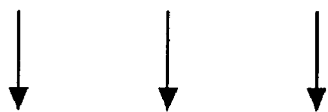


Fig. 8D

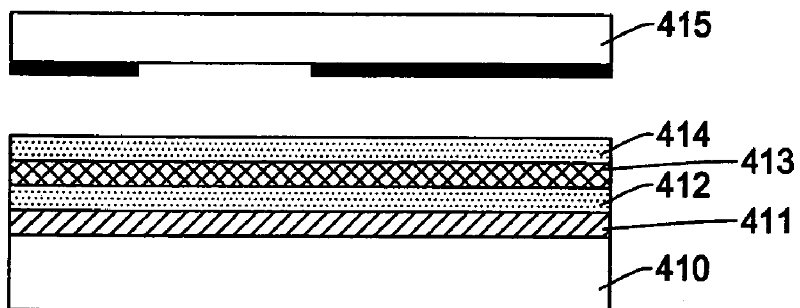


Fig. 8E

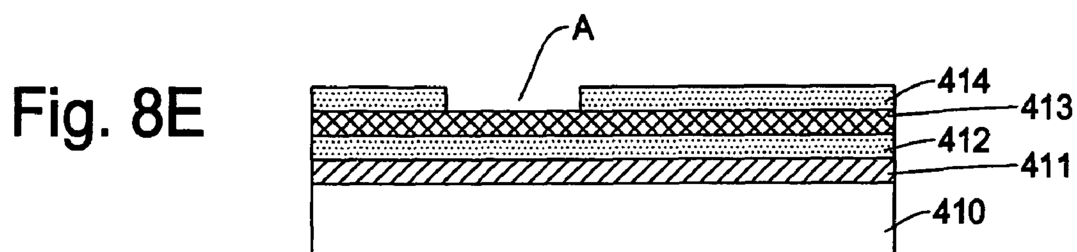


Fig. 8F

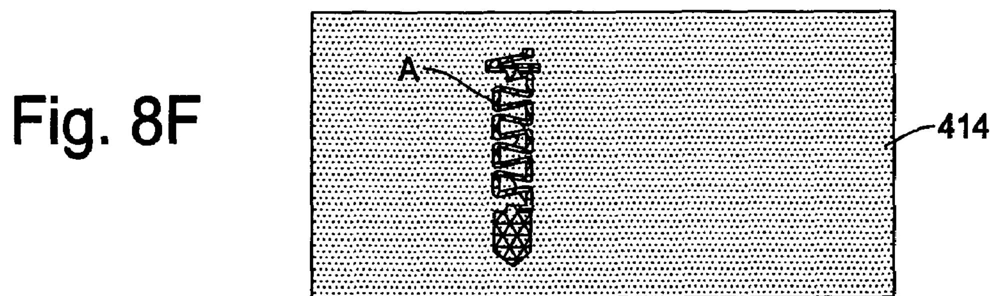


Fig. 8G

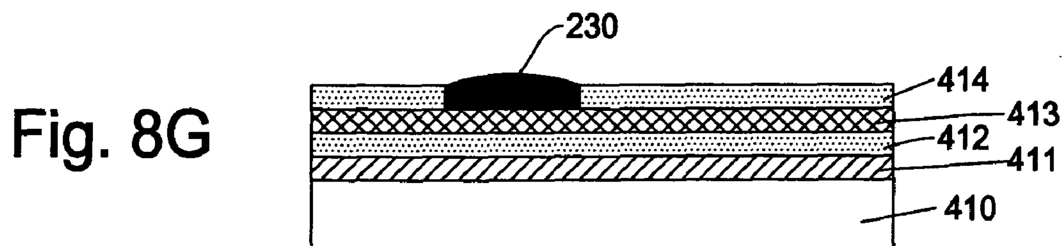


Fig. 8H

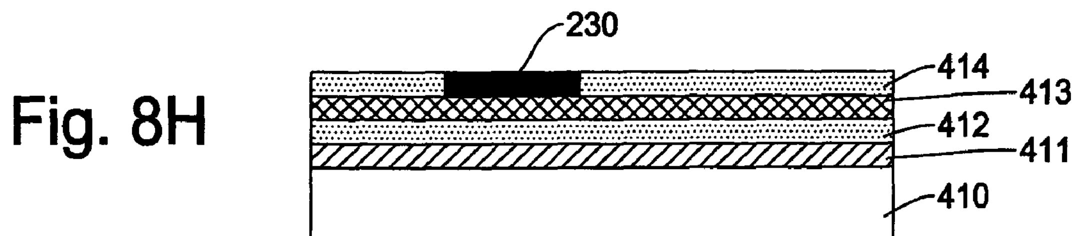


Fig. 8I

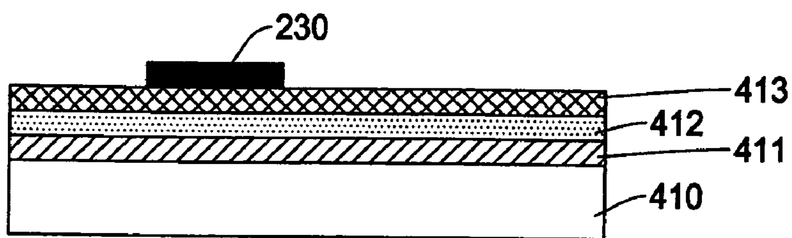


Fig. 8J

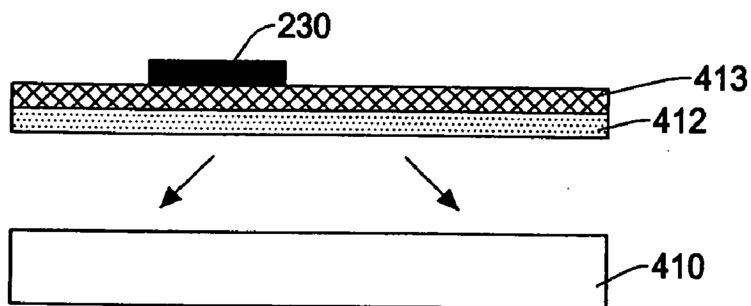


Fig. 8K

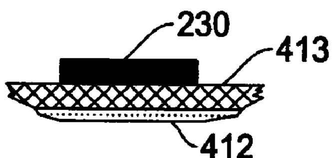
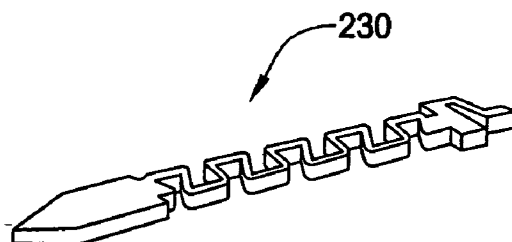


Fig. 8L



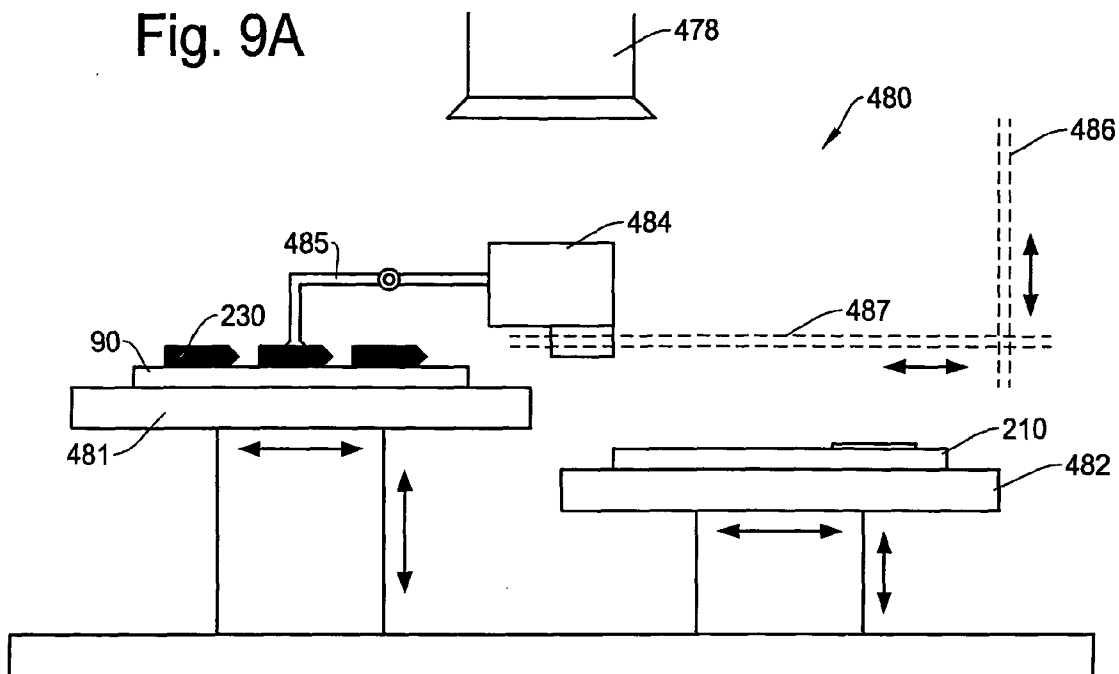


Fig. 9A
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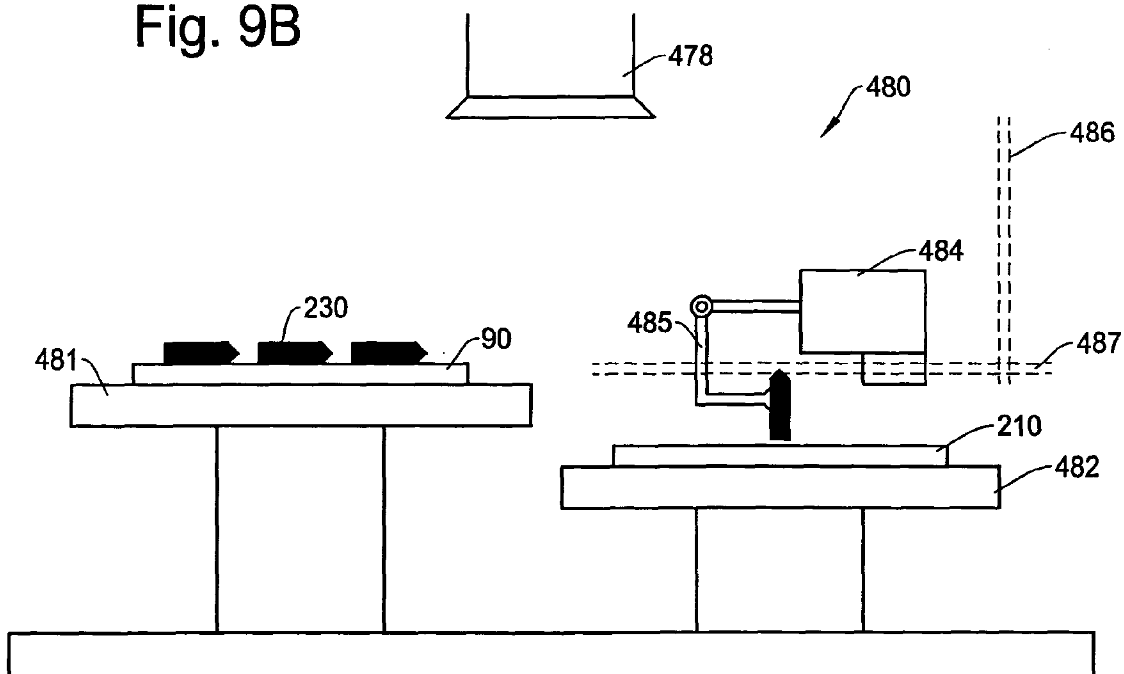
Fig. 9B
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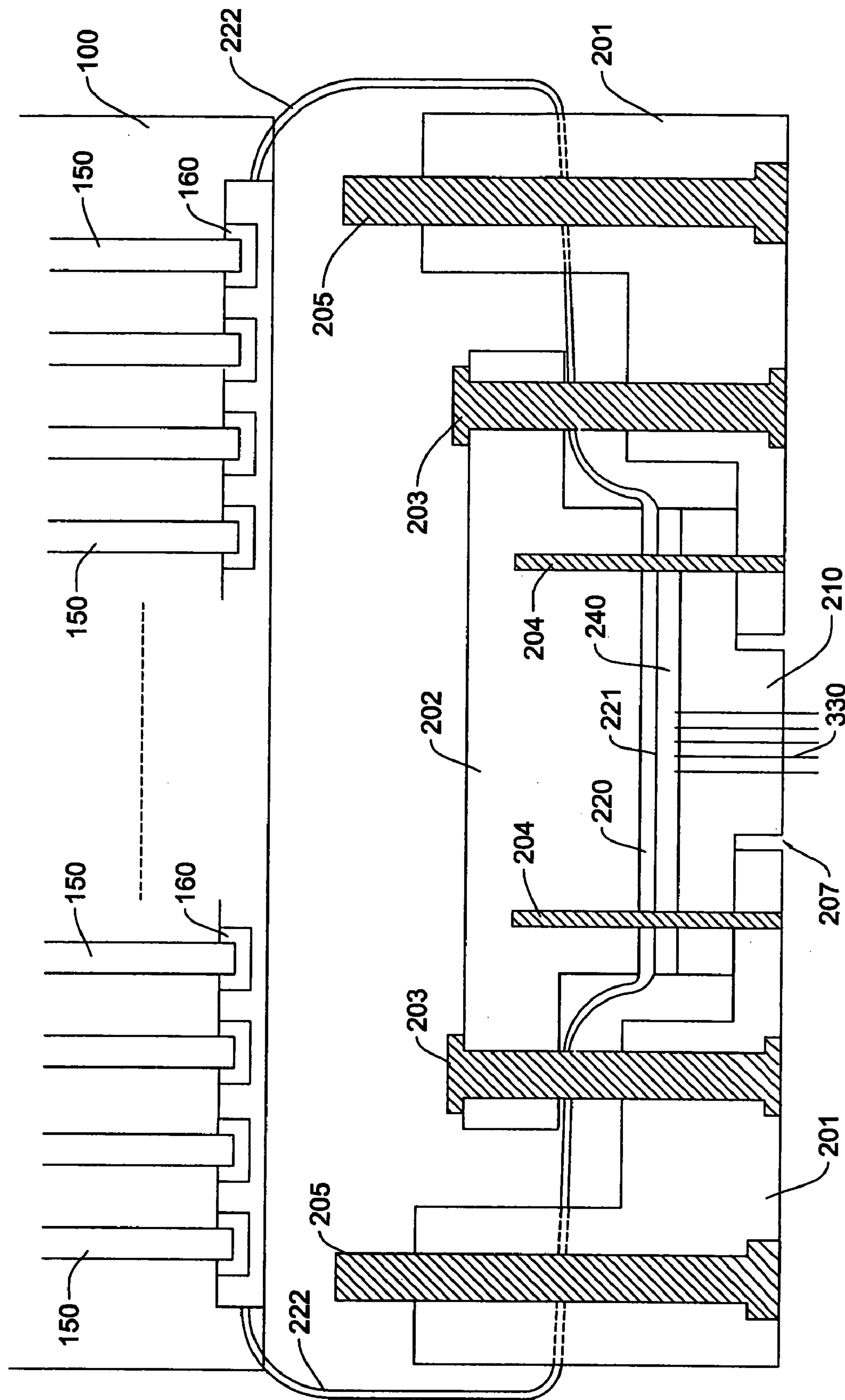
Fig. 10
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Fig. 11

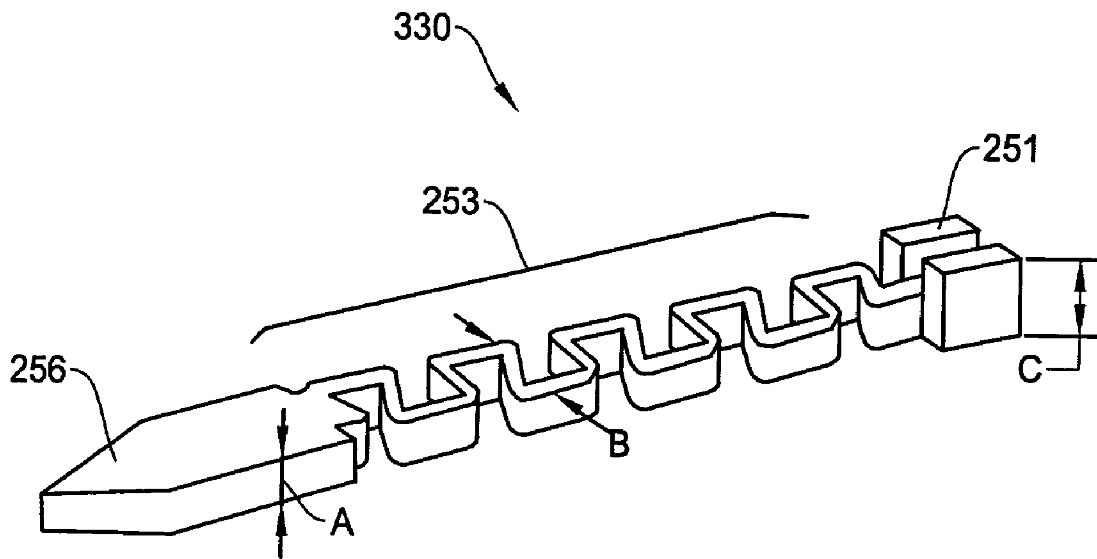


Fig.12A

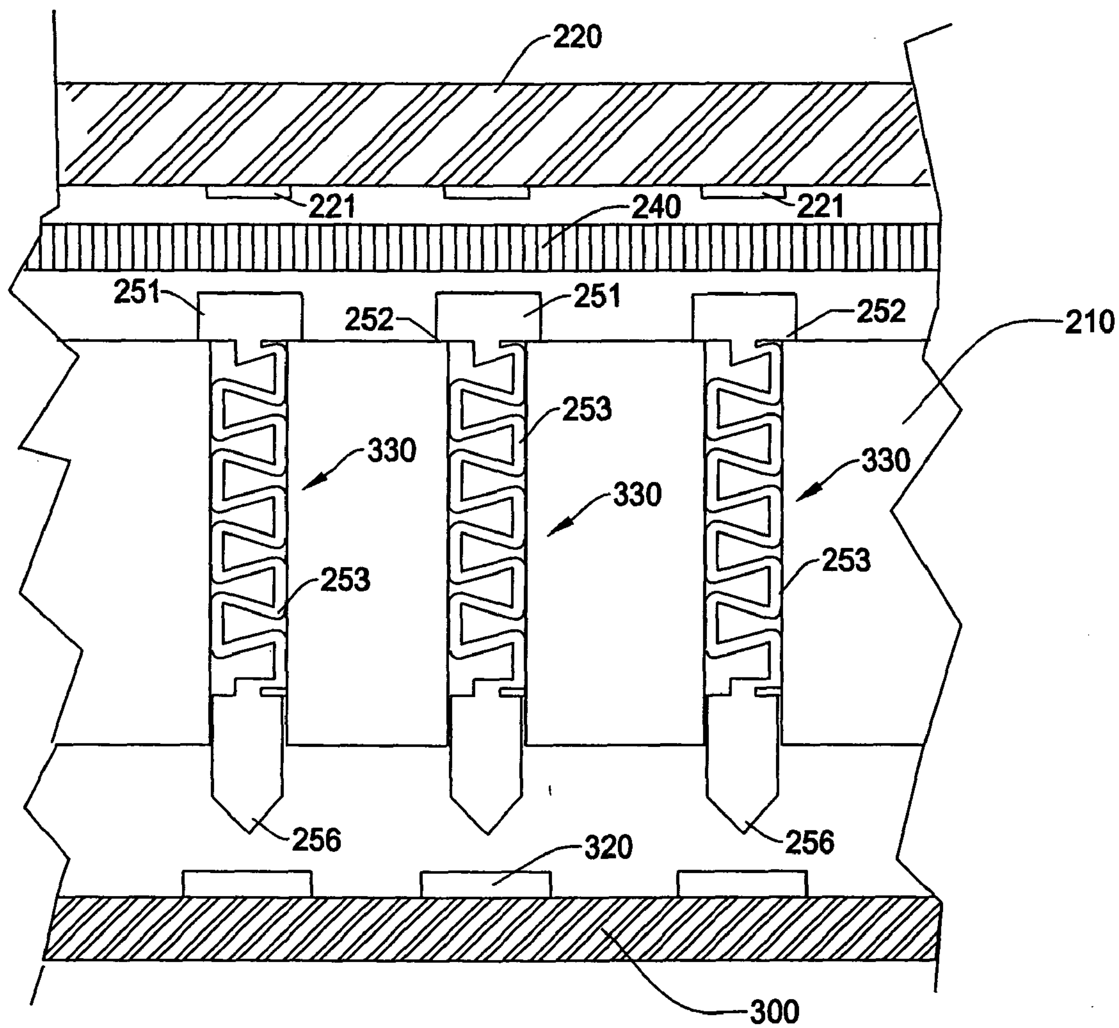


Fig.12B

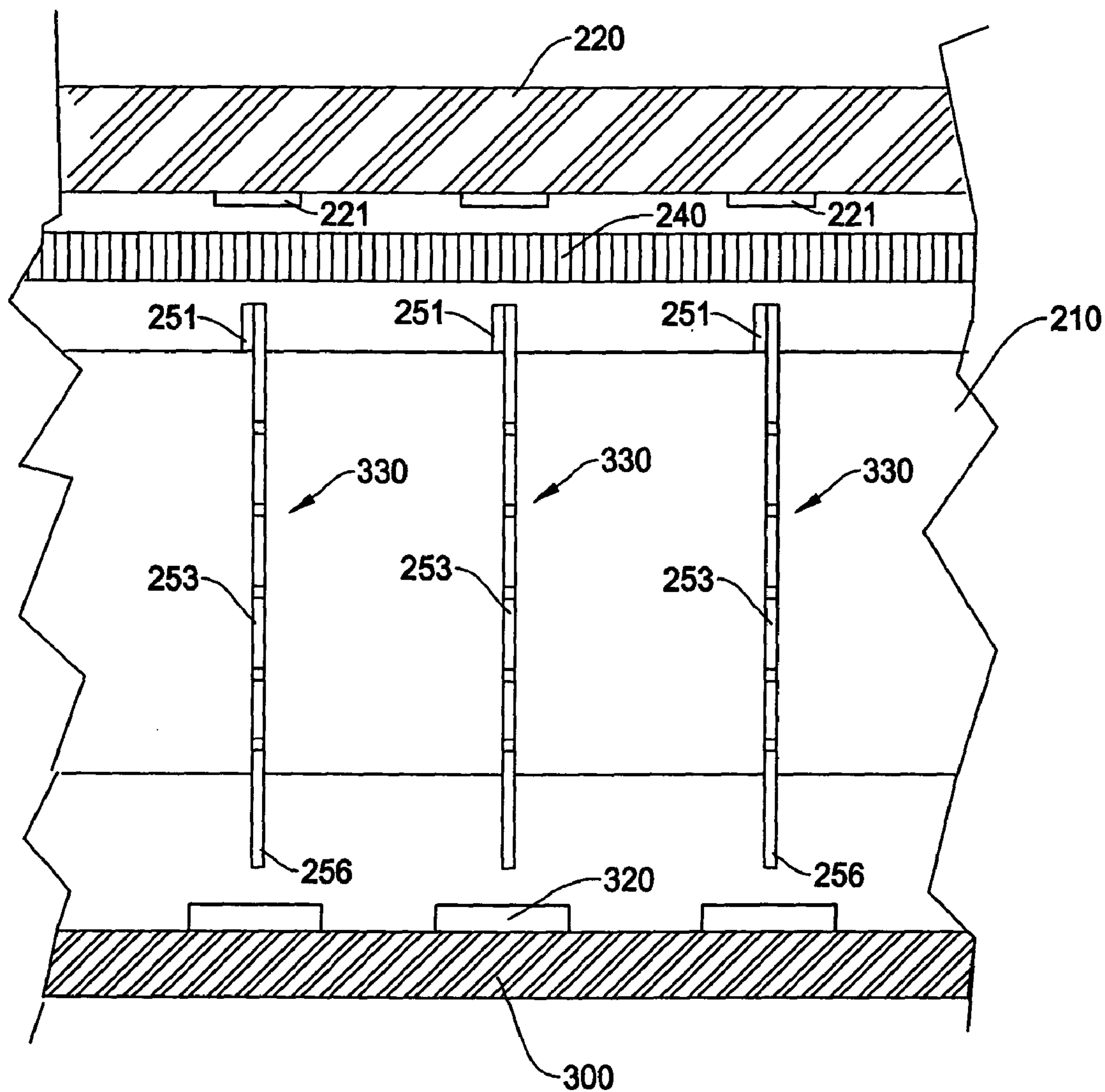


Fig. 13A

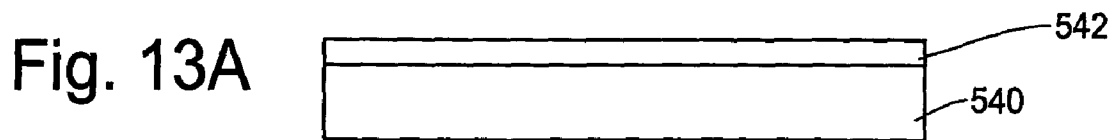


Fig. 13B

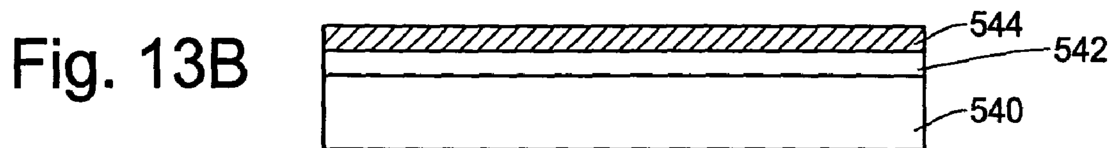


Fig. 13C

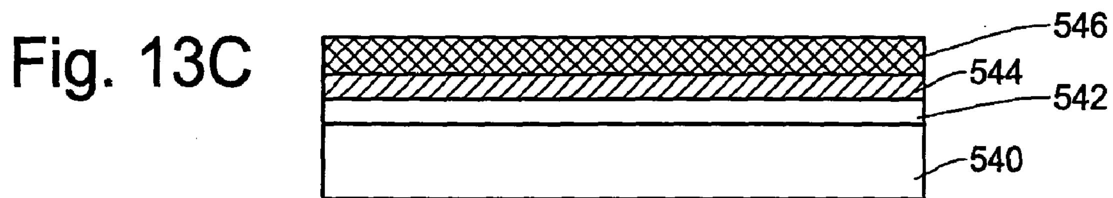


Fig. 13D

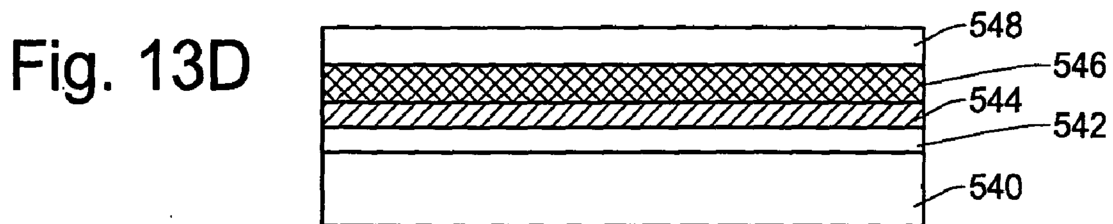


Fig. 13E

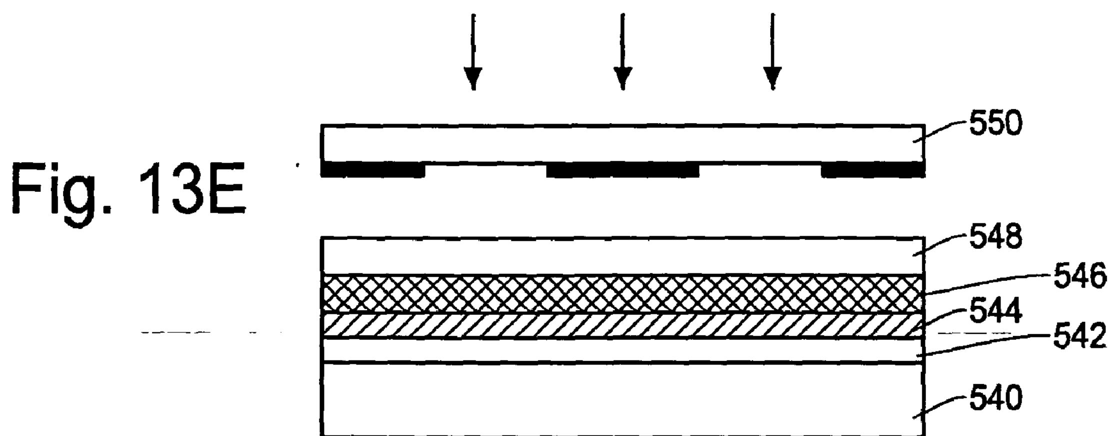


Fig. 13F

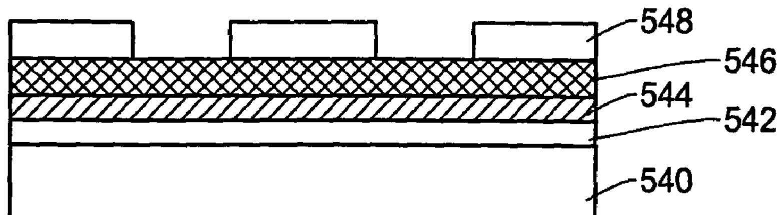


Fig. 13G

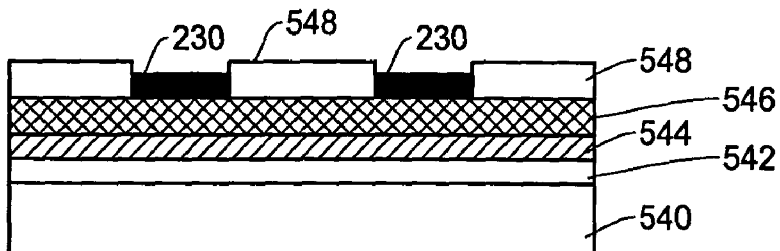


Fig. 13H

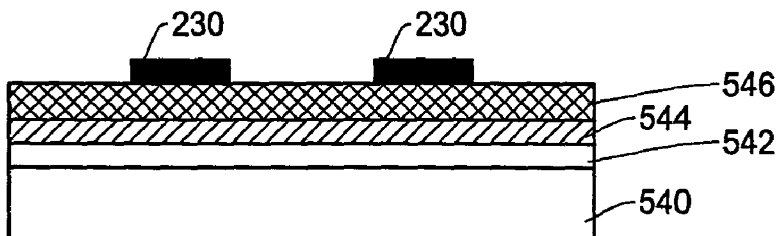


Fig. 13I

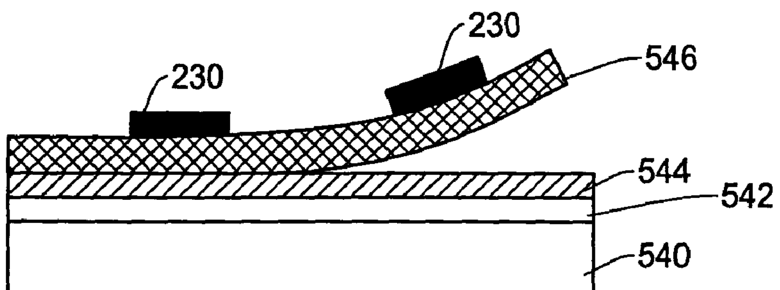


Fig. 13J

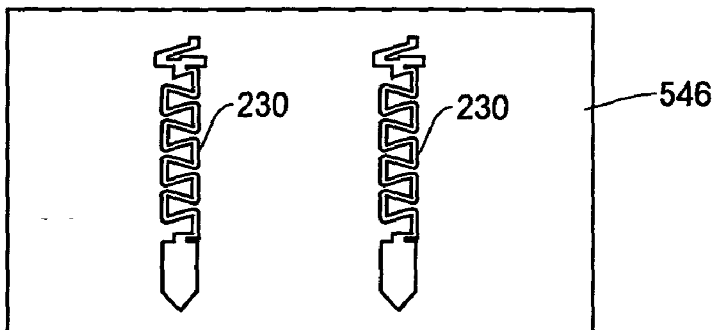


Fig. 13K

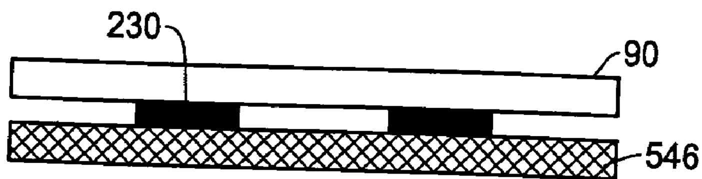


Fig. 13L

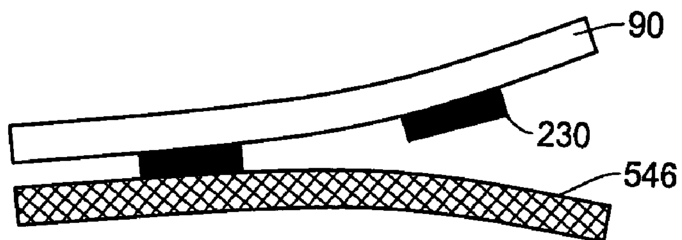


Fig. 13M

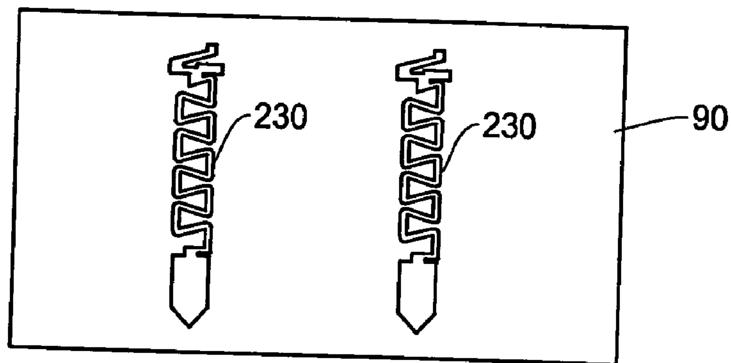
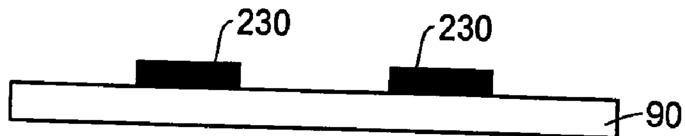


Fig. 13N



PROBE CONTACT SYSTEM USING FLEXIBLE PRINTED CIRCUIT BOARD

FIELD OF THE INVENTION

[**0001**] This invention relates to a contact structure to establish electrical connection with contact targets such as contact pads on semiconductor devices, and more particularly, to a probe contact system using a flexible printed circuit board and a plurality of contactors mounted on a contactor carrier for testing semiconductor devices with high speed, high density and low cost.

BACKGROUND OF THE INVENTION

[**0002**] In testing high density and high speed electrical devices such as LSI and VLSI circuits, a high performance probe contact system has to be used. The probe contact system typically includes a contact substrate (space transformer) having a large number of contactors or probe elements, a probe card for mounting the contact substrate, and a plurality of pogo-pins for connecting between the probe card and a test head of a semiconductor test system. The probe contact system interfaces between the test head of the semiconductor test system and semiconductor devices to test or burn-in IC chips, semiconductor wafers, printed circuit boards and the like.

[**0003**] In case where semiconductor devices to be tested are in the form of a semiconductor wafer, a semiconductor test system such as an IC tester is usually connected to substrate handler, such as an automatic wafer prober, to automatically test the semiconductor wafer. **FIG. 1** shows an example of a combination of a semiconductor test system **10** and a wafer prober (substrate handler). The semiconductor test system **10** has a test head **100** which is ordinarily in a separate housing and electrically connected to the test system with a bundle of cables **110**. The test head **100** and the substrate handler **400** are mechanically as well as electrically connected with each other with the aid of a manipulator **500** which is driven by a motor **510**. The semiconductor wafers to be tested are automatically provided to a test position of the test head **100** by the substrate handler **400**.

[**0004**] **FIG. 2** shows the connection between the test system and the substrate handler in more detail. The test head **100** and the substrate handler **400** are connected through an interface component (probe contact system) **140** consisting of a performance board **120**, signal cables **124** such as coaxial cables, a pin block structure including a pogo-pin block **130** and contact pins (pogo-pins) **141**, a probe card (**170**) and contactors **190**. The test head **100** includes a large number of printed circuit boards (pin cards) **150** which correspond to the number of test channels (pins) of the semiconductor test system. Each of the printed circuit boards **150** has a connector **160** to receive a corresponding contact terminal **121** of the performance board **120**.

[**0005**] The pogo-pin block **130** is mounted on an upper surface of a frame (not shown) of the substrate handler **400**. A large number of pogo-pins **141** are mounted on the pogo-pin block **130**. As is well known in the art, a pogo-pin is a compressive contact pin having a spring therein. The pogo-pin block **130** is to accurately hold the pogo-pins **141** relative to the probe card **170** and the substrate handler **400**. In the substrate handler **400**, a semiconductor device, such as a semiconductor wafer **300** to be tested is mounted on a chuck **180**.

[**0006**] Contact pads (electrodes) on the upper surface of the probe card **170** are electrically connected to the pogo-pins **141** when the pogo-pin block **130** is pressed against the probe card **170**. Because each pogo-pin **141** is elastic in the longitudinal direction by the spring therein, it is able to overcome the planarization problem (unevenness of the surface flatness) involved in the probe card, wafer prober frames, or the like. The pogo-pins **141** are also connected to the contact terminals **121** of the performance board **120** through the coaxial cables **124** where each contact terminal **121** of the performance board **120** is connected to the printed circuit boards **150** of the test head **100**. Further, the printed circuit boards **150** are connected to the semiconductor test system through the cable **110** having several hundreds of inner cables.

[**0007**] The probe contactors **190** mounted on the probe card **170** through a space transformer (not shown) contact with the surface (contact targets) of the semiconductor wafer **300** on the chuck **180** to apply test signals to the semiconductor wafer **300** and receive the resultant output signals from the semiconductor wafer **300**. The resultant output signals from the wafer **300** under test are compared with the expected data generated by the semiconductor test system to determine whether the IC circuits on the semiconductor wafer **300** function correctly.

[**0008**] **FIG. 3** is a cross sectional view showing an example of probe contact system formed with a pogo-pin block **130**, a probe card **60**, a space transformer (contact substrate) **50**, and a contactor carrier **40**. Typically, the contactor carrier **40** is provided with a large number of contactors **30**. In the example of **FIG. 3**, the space transformer **50** is incorporated to fan-out the small pitch of the contactors **30** on the contactor carrier **40** to the large pitch of the contact pads **62** on the probe card **60**. The space transformer **50** has a large number of inner patterns **52** and **54** to change the space (pitch) of the connectors **30**. The space transformer **50** has many signal patterns and is made of, for example, multi-layers of ceramic substrate, and is costly.

[**0009**] Interconnect traces **63** of the probe card **60** further fans-out the pitch so that contact pads **65** of the probe card **60** can contact with pogo-pins **141** of the pogo-pin block **130**. **FIG. 3** further shows a semiconductor wafer **300** having contact pads **320** thereon as contact targets. The pogo-pin block **130** and probe card **60** in **FIG. 3** respectively correspond to the pogo-pin block **130** and probe card **60** in **FIG. 2**. Thus, the pogo-pin block **130** has a large number of pogo-pins (contact pins) **141** to interface between the probe card **60** and the performance board **120** (**FIG. 2**). At upper ends of the pogo-pins **141**, cables **124** such as coaxial cables are connected to transmits signals to the printed circuit boards (pin cards) **150** in the test head **100** through the performance board **120**.

[**0010**] As shown in **FIG. 3**, the carrier **40** is provided with plurality of contactors **30**. The carrier **40** is so positioned over the contact targets such as contact pads **320** on a semiconductor wafer **300** to be tested that the contactors **30** establish electrical connections with the semiconductor wafer **300** when pressed against the other. Although only two contactors **30** are shown in **FIG. 3**, a large number, such as several hundreds or several thousands of contactors **30** are aligned on the carrier **40** in actual applications such as semiconductor wafer testing.

[0011] The contactor **30** in this example has a top contact portion protruding through the top surface of the carrier **40** to electrically connect with the contact pad of the space transformer **50**, a body portion that is housed in the via hole of the carrier **40**, a spring portion projected from the bottom surface of the carrier **40** and bent to produce a resilient contact force when pressed against the contact target, and a bottom contact portion that establishes electrical contact with the contact targets **320** on the wafer **300**. The contactors **30** can be made through a semiconductor production process including, for example, photolithography and electroplating process on a silicon substrate.

[0012] When the semiconductor wafer **300** moves upward, the contactors **30** and the contact targets **320** on the wafer **300** mechanically and electrically contact with each other. Consequently, a signal path is established from the contact target **320** to test head of the semiconductor test system through the contactors **30** on the contactor carrier **40**, pads and interconnect trace **54** of the space transformer **50**, contact pads **62**, **65**, and interconnect trace **63** on the probe card **60**, and pogo-pin block **130**.

[0013] In the foregoing conventional example, to establish electrical connection with the contact pads of the semiconductor wafer, the probe contact system having many components has to be used, resulting in high cost. Since the semiconductor industry is under the continued demands of improving performances per cost, it is necessary to decrease the test cost involved in testing the semiconductor devices. Under the circumstances, there is a need in the industry to incorporate a simpler and more economical way to form a probe contact system for a semiconductor test system.

SUMMARY OF THE INVENTION

[0014] Therefore, it is an object of the present invention to provide a probe contact system to establish electrical connection with contact targets with a simple structure, low cost and high performance.

[0015] It is another object of the present invention to provide a probe contact system having a flexible printed circuit board, thereby eliminating the pogo-pin block, pogo-pins, coaxial cables, probe card and space transformer in the conventional technology.

[0016] It is a further object of the present invention to provide a probe contact system having a plurality of contactors made on a planar surface of a substrate in a two-dimensional manner and mounted on a carrier in a three-dimensional manner.

[0017] In one aspect of the present invention, the probe contact system includes: a main frame having an opening on a bottom at about a center thereof; a contactor carrier attached to the main frame, the contactor carrier mounting a plurality of contactors in a manner that lower ends of the contactors being projected from a lower surface of the contactor carrier through the opening of the main frame and top ends of the contactors being projected from an upper surface of the contactor carrier; a flexible printed circuit board having contact pads at a center area thereof and signal lines connected to the contact pads and extended to an end of the flexible printed circuit board, the center area of the flexible printed circuit board being mounted on the contactor carrier in a manner that the top ends of the contactors contacting with the contact pads on the flexible printed circuit board.

[0018] One of the essential features in the first aspect of the present invention resides in that each of the contactors has a top spring for resiliently contacting the top end with the contact pad on the flexible printed circuit board, and the end of the flexible printed circuit board with the signal lines is connected to a test head of the semiconductor test system.

[0019] Each contactor includes a stopper to position the contactor on the contactor carrier when the contactor is inserted in a through hole of the contactor carrier. The top spring of the contactor is provided between the top end and the stopper. Each of the contactors further comprises a main spring between a lower end and the stopper for producing a resilient contact force when the lower end is pressed against the contact target. The top spring is formed of a diagonal beam and the main spring is formed of a plurality of zig-zag shaped spring elements.

[0020] The flexible printed circuit board has two ends extended from the center area and connected to the test head of the semiconductor test system. Alternatively, the flexible printed circuit board has four ends extended from the center area and connected to the test head of the semiconductor test system. A pitch between two signal lines on the flexible printed circuit board at the contact center area is smallest and is enlarged toward the end of the flexible printed circuit board.

[0021] In the second aspect of the present invention, the probe contact system includes: a main frame having an opening on a bottom at about a center thereof; a contactor carrier attached to the main frame, the contactor carrier mounting a plurality of contactors in a manner that lower ends of the contactors being projected from a lower surface of the contactor carrier through the opening of the main frame and top ends of the contactors being projected from an upper surface of the contactor carrier; a conductive elastomer sheet provided on the contactor carrier in a manner that the top ends of the contactors contacting with a lower surface of the conductive elastomer sheet; a flexible printed circuit board having contact pads at a center area thereof and signal lines connected to the contact pads and extended to an end of the flexible printed circuit board, the center area of the flexible printed circuit board being provided on the conductive elastomer sheet in a manner that an upper surface of the conductive elastomer sheet contacting with the contact pads on the flexible printed circuit board.

[0022] One of the essential features in the second aspect of the present invention resides in that the top end of the contactor is electrically connected to the contact pad on the flexible printed circuit board through the conductive elastomer sheet, and the end of the flexible printed circuit board with the signal lines is connected to a test head of the semiconductor test system.

[0023] According to the present invention, the probe contact system has a simple structure by eliminating many components used in the conventional technology. Namely, by incorporating the flexible printed circuit board, the probe contact system of the present invention is established without using the pogo-pin block, pogo-pins, coaxial cables, probe card and space transformer in the conventional technology. The flexible printed circuit board has signal patterns and works as a space transformer by changing pitches of the contactors to the pitches of the socket in the test head. The flexible printed circuit board works as signal cables for

connecting the contactors with the test head, thereby obviating the probe card, pogo-pins and coaxial cables in the conventional technology.

[0024] The probe contact system of the present invention has a broad bandwidth covering high frequency region to meet the test requirements of next generation semiconductor technology. Since a large number of contactors are produced at the same time on a substrate trough a semiconductor production process, it is possible to achieve consistent quality, high reliability and long life in the contactor performance as well as low cost. Further, according to the present invention, the production process is able to produce a large number of contactors in a horizontal direction on the silicon substrate by using relatively simple technique. Such contactors are mounted on a contactor carrier in a vertical direction. The probe contact system in the present invention is low cost, and has high efficiency, high mechanical strength and reliability.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] **FIG. 1** is a schematic diagram showing a structural relationship between a substrate handler and a semiconductor test system for testing semiconductor devices.

[0026] **FIG. 2** is a schematic diagram showing an example of structure including a conventional probe contact system for connecting the test head of the semiconductor test system to the substrate handler.

[0027] **FIG. 3** is a cross sectional view showing an example of a probe contact system using the conventional contact structure for interfacing between the semiconductor device under test and the test head of the semiconductor test system.

[0028] **FIG. 4** is a schematic diagram showing an example of a probe contact system using a flexible printed circuit board in accordance with the present invention.

[0029] **FIGS. 5A and 5B** are schematic plan views showing examples of the flexible printed circuit board incorporated in the probe contact system of **FIG. 4**.

[0030] **FIG. 6** is a partial cross sectional view showing an example of the probe contact system of the present invention using the flexible printed circuit board of **FIGS. 5A-5B**.

[0031] **FIGS. 7A-7B** are schematic diagrams showing a basic concept for producing the contactors of the present invention in which a large number of contactors are formed on a planar surface of a substrate and removed therefrom for being mounted on the contactor carrier.

[0032] **FIGS. 8A-8L** are schematic diagrams showing an example of production process for producing the contactors of the present invention on a planar surface of a substrate in a two dimensional manner.

[0033] **FIGS. 9A-9B** are schematic diagrams showing an example of pick and place mechanism and its process for picking the contactors and placing the same on the contactor carrier to establish the probe contact system of the present invention.

[0034] **FIG. 10** is a schematic diagram showing another example of a probe contact system of the present invention using a conductive polymer sheet and contactors without having top springs.

[0035] **FIG. 11** is a perspective view showing another example of contactor of the present invention for use in the probe contact system of **FIG. 10**.

[0036] **FIG. 12A** is a partial cross sectional front view showing the probe contact system of **FIG. 10**, and **FIG. 12B** is a partial cross sectional side view of the contact probe contact system of **FIG. 10**.

[0037] **FIGS. 13A-13N** are schematic diagrams showing another example of production process for producing the contactors of the present invention on a planar surface of a substrate in a two dimensional manner.

DETAILED DESCRIPTION OF THE INVENTION

[0038] Examples of probe contact system of the present invention and examples of contactors for use in the probe contact system will be described with reference to **FIGS. 4-13N**. Although the present invention will be described for the case of testing a semiconductor wafer, the contact structure of the present invention can be used in testing LSI and VLSI chips, printed circuit boards and the like, or burning-in the semiconductor wafers and chips.

[0039] **FIG. 4** is a cross sectional view of the probe contact system using the present invention. The test head **100** of the semiconductor test system is illustrated over the probe contact system. The probe contact system of **FIG. 4** includes a main frame **201**, a contactor carrier **210** mounted on a hollow portion of the main frame **201**, a frame adaptor **202** for mounting the contactor carrier **210**, and a flexible printed circuit board **220**. A plurality of contactors **230** are mounted on the contactor carrier **210**.

[0040] In this example, the probe contact system has a structure which is much simpler than that of the conventional probe contact system such as shown in **FIG. 3**. Namely, the pogo-pins **141**, probe card **60** and space transformer **50** in **FIG. 3** are eliminated in the probe contact system of the present invention. Instead of such components used in the conventional technology, the probe contact system of **FIG. 4** utilizes the flexible printed circuit board (hereafter "flexible PCB") **220**.

[0041] The flexible PCB **220** plays an important role to cover the functions of the pogo-pins **141**, coaxial cables **124**, probe card **60**, and the space transformer **50** in the conventional technology. In the present invention, the flexible PCB **220** transforms the space (pitch) and directly communicates with the PCB boards (pin cards) **150** in the test head **100** through the connectors **160**. As a result, the probe contact system is able to dramatically reduce the cost because the probe card **60**, pogo-pins **141**, and the space transformer **50** are relatively expensive.

[0042] The main frame **201** has, for example, a circular shape on which an opening **207** is formed at about a center bottom thereof for the contactors **230** to project from the bottom surface of the main frame **201** and the contactor carrier **210**. The main frame **201** is attached to a substrate handler, such as an automatic wafer prober or an automatic test handler in a manner shown in **FIG. 1** through screws (bolts) **205**. The screws **205** can be differential screws or equivalent thereof to adjust the planarity of the top ends of the contactors **230** relative to the contact targets.

[0043] The contactor carrier **210** is mounted on the main frame **201** through the frame adaptor **202**. In this example, screws (bolts) **203** are used to fix the frame adaptor **202** to the main frame **201** while the contactor carrier **210** is clamped therebetween. Preferably, alignment pins **204** are used to align the relative positions among the main frame **201**, frame adaptor **202**, flexible PCB **220**, and the contactor carrier **210**. The flexible PCB **220** is sandwiched between the frame adapter **202** and the contactor carrier **210** at about the center thereof.

[0044] **FIGS. 5A and 5B** are plan views showing examples of the flexible PCB **220** incorporated in the probe contact system of the present invention. In the example of **FIG. 5A**, the flexible PCB **220** is extended in two directions, and in the example of **FIG. 5B**, the flexible PCB **220** is extended in four directions. The flexible PCB **220** has a plurality of contactor bases (contact pads) **221** at a center area and signal lines **272** connected to the contact pads and extended to the ends of the flexible PCB. The head of each contactor **230** contacts with the corresponding contact pad **221** on the flexible PCB **220** as shown in **FIG. 4**. In an actual application, a cable portion **222** of the flexible PCB **220** is longer than that shown in the drawings. The cable portions **222** are extended to the test head **100** of the semiconductor test system as shown in **FIG. 4**.

[0045] The flexible PCB **220** is typically made of polyimide, polyester or epoxy woven fiberglass. The flexible PCB **220** is either single sided or double sided and typically covered by an insulation layer while the contact pads **221** are exposed at the bottom surface of the flexible PCB **220**. The signal lines **272** on the flexible PCB **220** are made of conductive materials such as nickel, copper or gold on the surface thereof or between two polyimide layers. As noted above, the cable portions **222** are directly connected to the test head **100** of the semiconductor test system.

[0046] The signal lines **272** change the small pitch of the contactors **230** and the contact pads **221** to the pitch of the socket **160** on the test head **100** which is much larger than that of the contactors. Namely, a pitch (distance) between two signal lines **272** at the contact pads **221** is smallest and is enlarged toward the end of the flexible PCB **200**. In other words, the flexible PCB **220** in the probe contact system works as the space transformer, pogo-pins and coaxial cables in the conventional technology.

[0047] **FIG. 6** is a partial cross sectional view of the probe contact system of the present invention showing the flexible PCB **220**, the contactors **230** mounted on the contactor carrier **210** and the semiconductor wafer **300** under test. As shown in **FIGS. 5A and 5B**, the flexible PCB **220** has a plurality of contact pads **221** which contact with the top ends of the contactors **230**. The semiconductor wafer **300** under test has a plurality of contact pads (contact targets) **320** which are probed by the contactors **230**.

[0048] The contactor **230** has a top end **235** which contacts with the contact pad **221** on the flexible PCB **220**, a top spring **231** formed of a diagonal beam, a stopper **232** which engages with the contactor carrier **210**, a main spring **233**, and a lower end **236** which is a contact point. Each of the spring contactors **230** is inserted in a through hole of the contactor carrier **210**. The top end **235** and the top spring **231** are projected from the top surface of the contactor carrier **210**. The main spring **233** is formed of a plurality of zig-zag shaped spring elements and is substantially encapsulated by the through hole of the contactor carrier **210** and the lower end **236** is projected from the bottom surface of the contactor carrier **210**.

[0049] The stopper **232** of the contactor **230** is larger than the dimension of the through hole to engage with the upper surface of the contactor carrier **210**. The stopper **232** is provided to securely mount the spring contactor **230**, and at the same time, to keep the height of the upper end **235** of each spring contactor constant. The top spring **231** produces a resilient contact force when the top end **235** is pressed against the contact pad **221**. The main spring **233** is configured by several spring elements and produces a resilient contact force when the lower end **236** is pressed against the contact pad **320** on the semiconductor wafer **300** under test. The resiliency of the contactor **230** promotes a scrubbing effect that occurs at the contact point in which the oxide layer is pierced by the contactors to promote a high connection performance.

[0050] As an example of the size of the contactor **230**, a thickness is 30-50 micrometer, a width is 150-200 micrometer, and an overall length is 800-1,600 micrometer. As noted above, the stopper **232** has a size larger than the other part of the contactor so that the contactor **230** is stopped when the stopper **232** engages with the surface of the contactor carrier **210**. The upper end **235** and lower end **236** of the spring contactor **230** function as contact points to establish electrical communication with other components. In the semiconductor test application, the upper end **235** contacts with the contact pad **221** on the flexible PCB **220**, and the lower end **236** contacts with the contact pad **320** on the semiconductor wafer **300** under test.

[0051] **FIGS. 7A-7B** show a basic concept for producing the contactors **230** of the present invention. As shown in **FIG. 7A**, the contactors **230** are produced on a planar surface of a substrate **410** in a horizontal direction, i.e., in parallel with a planar surface of the substrate **410**. In other words, the contactors **230** are built in a two dimensional manner on the substrate **410**. Then, the contactors **230** are removed from the substrate **410** and mounted on the contactor carrier **210** as shown in **FIGS. 4 and 6** in a vertical direction, i.e. in a three dimensional manner. Typically, the substrate **410** is a silicon substrate although other types of substrate are also feasible.

[0052] In the example of **FIG. 7B**, after producing the contactors **230** on the planar surface of the substrate **410**, the contactors **230** are transferred from the substrate **410** to an adhesive member **90**, such as an adhesive tape or plate. Then, in the further process, the contactors **230** on the adhesive tape **90** are removed therefrom to be mounted on the contactor carrier **210** of **FIGS. 4 and 6** in a vertical direction, i.e., in a three dimensional manner with use, for example, of a pick and place mechanism.

[0053] **FIGS. 8A-8L** are schematic diagrams showing an example of production process for producing the contactors of the present invention. In **FIG. 8A**, a sacrificial layer **411** is formed on a base substrate **410** which is typically a silicon substrate. Other substrate is also feasible such as a glass substrate, a ceramic substrate or other dielectric substrate. The sacrificial layer **411** is made, for example, of silicon dioxide (SiO_2) through a deposition process such as a chemical vapor deposition (CVD). The sacrificial layer **411**

is to separate the contactors from the silicon substrate **410** in the later stage of the production process.

[**0054**] An adhesion promoter layer **412** is formed on the sacrificial layer **411** such as shown in **FIG. 8B** through, for example, an vapor process. An example of material for the adhesion promoter layer **412** includes chromium (Cr) and titanium (Ti) with the thickness of about 200-1,000 angstroms, for example. The adhesion promoter layer **412** is to facilitate the adhesion of conductive layer **413** of **FIG. 8C** on the silicon substrate **410**. The conductive layer **413** is made, for example, of copper (Cu) or Nickel (Ni), with a thickness of about 1,000-5,000 angstroms, for example. The conductive layer **413** is to establish electrical conductivity for an electroplating process in the later stage.

[**0055**] In the next process, a photoresist layer **414** is formed on the conductive layer **413** over which a photo mask **415** is precisely aligned to be exposed with ultraviolet (UV) light as shown in **FIG. 8D**. The photo mask **415** shows a two dimensional image of the spring contactor which will be developed on the photoresist layer **413**. As is well known in the art, positive as well as negative photoresist can be used for this purpose. If a positive acting resist is used, the photoresist covered by the opaque portion of the mask **415** hardens (cure) after the exposure. In the development process, the exposed part of the resist can be dissolved and washed away, leaving a photoresist layer **414** of **FIG. 8E** having an opening or pattern "A" on the photoresist layer **414** having the image (shape) of the contactor **230**. **FIG. 8F** shows a plan view of the pattern "A" on the substrate showing the shape of the contactor **230**.

[**0056**] In the photolithography process in the foregoing, instead of the UV light, for creating the pattern "A" shown in **FIGS. 8E and 8F**, it is also possible to expose the photoresist layer **414** with an electron beam or X-rays as is known in the art. Further, it is also possible to directly write the image of the contact structure on the photoresist layer **414** by exposing the photoresist **414** with a direct write electron beam, X-rays or light source such as a laser.

[**0057**] The conductive material such as copper (CU), nickel (Ni), aluminum (Al), rhodium (Rh), palladium (Pd), tungsten (W) or other material, nickel-cobalt (NiCo) or other alloy combinations thereof is deposited (electroplated) in the pattern "A" of the photoresist layer **414** to form the spring contactor **230** as shown in **FIG. 8G**. Preferably, a conductive material which is different from that of the conductive layer **413** should be used to differentiate etching characteristics from one another as will be described later. The over plated portion of the contactor **230** in **FIG. 8G** is removed in the grinding (planarizing) process of **FIG. 8H**.

[**0058**] The above noted process may be repeated for producing contactors having different thickness by forming two or more conductive layers. For example, a certain portion of the contactor may be designed to have a thickness larger than that of the other portions. Such a contactor is shown in **FIGS. 11 and 12**B in which a top end portion **251** has a larger thickness than the other portions. In such a case, after forming a first layer of the contactors (conductive material), if necessary, the process of **FIGS. 8D-8H** will be repeated to form a second layer or further layers on the first layer of the contactors.

[**0059**] In the next process, the photoresist layer **414** is removed in a resist stripping process as shown in **FIG. 8I**. Typically, the photoresist layer **414** is removed by wet chemical processing. Other example of stripping methods includes acetone-based stripping and plasma °2 stripping. In **FIG. 8J**, the sacrificial layer **411** is etched away so that the contactor **230** is separated from the base substrate **410**. Another etching process is conducted so that the adhesion promoter layer **412** and the conductive layer **413** are removed from the spring contactor **230** as shown in **FIG. 8K**.

[**0060**] The etching condition can be selected to etch the layers **412** and **413** but not to etch the spring contactor **230**. In other words, to etch the conductive layer **413** without etching the spring contactor **230**, as noted above, the conductive material used for the spring contactor must be different from the material of the conductive layer **413**. Finally, the spring contactor **230** is separated from any other materials as shown in the prospective view of **FIG. 8L**. Although the production process in **FIGS. 8A-8L** shows only one contactor **230**, in an actual production process, a large number of spring contactors are produced at the same time through the foregoing process.

[**0061**] **FIGS. 9A and 9B** are schematic diagrams showing an example of process for picking the contactors **230** from the adhesive tape **90** and placing the contactors on the contactor carrier **210**. The pick and place mechanism of **FIGS. 9A and 9B** is advantageously applied to the contactors **230** produced by the production process involving the adhesive tape **90** as shown in **FIG. 7B**. **FIG. 9A** is a front view of the pick and place mechanism **480** showing the first half process of the pick and place operation. **FIG. 9B** is a front view of the pick and place mechanism **480** showing the second half process of the pick and place operation.

[**0062**] In this example, the pick and place mechanism **480** is comprised of a transfer mechanism **484** to pick and place the contactors **230**, mobile arms **486** and **487** to allow movements of the transfer mechanism **480** in X, Y and Z directions, tables **481** and **482** whose positions are adjustable in X, Y and Z directions, and a monitor camera **478** having, for example, a CCD image sensor therein. The transfer mechanism **484** includes a suction arm **485** that performs suction (pick operation) and suction release (place operation) operations for the contactors **230**. The suction force is created, for example, by a negative pressure such as vacuum. The suction arm **485** rotates in predetermined angle such as 90 degrees.

[**0063**] In operation, the adhesive tape **90** having the contactors **230** and the contactor carrier **210** having the through holes are positioned on the respective tables **481** and **482** on the pick and place mechanism **480**. As shown in **FIG. 9A**, the transfer mechanism **480** picks the contactors **230** from the adhesive tape **90** by the suction force of the suction arm **485**. After picking the contactors **230**, the suction arm **485** rotates by 90 degrees, for example, as shown in **FIG. 9B**. Thus, the orientation of the spring contactor **230** is changed from the horizontal direction to the vertical direction. This operation change mechanism is just an example, and a person skilled in the art knows that there are many ways to change the orientation of the contactors. The transfer mechanism **480** then places the contactor **230** on the contactor carrier **210** where the contactors **230** are inserted in the through holes.

[**0064**] **FIG. 10** is a cross sectional view showing another example of the probe contact system of the present invention

using another type of the contactor. In this example, a conductive elastomer **240** is used between the flexible PCB **220** and the contactor carrier **210**. A plurality of contactors **330** are mounted on the contactor carrier **210**. In this embodiment, the contactor **330** does not have a spring at the top end. However, the conductive elastomer **240** establishes the elasticity to securely connect between the top end of the contactor **330** and the flexible PCB **220**. Other than the contactors **330** and the conductive elastomer **240**, the structure of the probe contact system of **FIG. 10** is basically the same as that shown in **FIG. 4**.

[0065] **FIG. 11** shows a perspective view of the contactor **330** used in the probe contact system of **FIG. 10**. The contactor **330** is configured by a top end **251**, a main spring **253** and a lower end **256**. As noted above, the contactor **330** of **FIG. 11** does not have a spring at the top. The top end **251** of the contactor **330** has a thickness greater than that of the other portions. For example, a thickness A of the main spring **253** and the lower end **256** is about 30-50 micrometer, a width B of the main spring and the lower end **256** is 150-200 micrometer, a thickness C of the top end **251** is 60-100 micrometer, and an overall length is 800-1,600 micrometer. As mentioned in the production process with reference to **FIGS. 8A-8L**, the increased thickness of the top end **251** is created by forming two or more conductive layers. The increased thickness of the top end **251** creates an increased contact area with respect to the conductive elastomer **240**, thereby improving the contact performance.

[0066] **FIGS. 12A and 12B** are partial cross sectional views showing the probe contact system of the present invention using the contactors shown in **FIG. 11**. **FIG. 12A** is a partial cross sectional front view, and **FIG. 12B** is a partial cross sectional side view of the contact probe contact system of **FIG. 10**. The probe contact system shows the flexible PCB **220**, conductive elastomer **240**, the contactors **330** mounted on the contactor carrier **210**, and the semiconductor wafer **300**.

[0067] As shown in **FIGS. 12A and 12B**, the contactor **330** is formed with the top end **251**, a stopper **252**, a main spring **253** and a lower end **256**. The stopper **252** has a width larger than that of the through hole of the contactor carrier **210** to stop the contactor **330** when inserted in the through hole. The main spring **253** is enclosed with the through hole of the contactor carrier **210** and elastically moved in the through hole when the lower end **256** is pressed against the contact target. As shown in **FIG. 12B**, the top end **251** of the contactor **330** has a larger thickness which also functions as the stopper.

[0068] The conductive elastomer sheet **240** is an elastic sheet with unidirectional conductivity by having a large number of conductive wires in a direction vertical with a surface of the contactor carrier **210**. The conductive elastomer sheet **240** is placed between the flexible PCB **220** and the contactor carrier **210** to establish electrical communication between the contact pads **221** and the top ends **251** of the contactor **330**. The conductive elastomer sheet **240** ensures the electrical communication by its elasticity and conductivity at the top of the contactor **330**. The main spring **253** ensures the electrical communication between the lower end **256** of the contactor **330** and the contact pads **320** on the semiconductor under test **300**.

[0069] **FIGS. 13A-13N** are schematic diagrams showing a further example of production process for producing the contactors **230** and **330** where the contactors are transferred to the adhesive tape. In **FIG. 13A**, an electroplate seed (conductive) layer **542** is formed on a base substrate **540** which is typically a silicon or glass substrate. The seed layer **542** is made of, for example, copper (Cu) or nickel (Ni), with a thickness of about 1,000-5,000 angstrom, for example. A chrome-inconel layer **544** is formed on the seed layer **542** as shown in **FIG. 13B** through, for example, a sputtering process.

[0070] In the next process in **FIG. 13C**, a conductive substrate **546** is formed on the chrome-inconel layer **544**. The conductive substrate **546** is made, for example, of nickel-cobalt (NiCo) with a thickness of about 100-130 micrometer. After passivating the conductive substrate **546**, a photoresist layer **548** with a thickness of about 100-120 micrometer is formed on the conductive substrate **546** in **FIG. 13D** and a photo mask **550** is precisely aligned so that the photoresist layer **548** is exposed with ultraviolet (UV) light as shown in **FIG. 13E**. The photo mask **550** shows a two dimensional image of the contactor **230** which will be developed on the surface of the photoresist layer **548**.

[0071] In the development process, the exposed part of the resist can be dissolved and washed away, leaving a photoresist layer **548** of **FIG. 13F** having a plating pattern transferred from the photo mask **550** having the image (shape) of the contactor **230**. In the step of **FIG. 13G**, conductive material is electroplated in the plating pattern on the photoresist layer **548** with a thickness of about 50-60 micrometer. An example of the conductive material is nickel-cobalt (NiCo). The nickel-cobalt contactor material will not strongly adhere to the conductive substrate **546** made of nickel-cobalt.

[0072] In the case where the contactor has two or more different thickness, such as the contactor **330** shown in **FIGS. 11 and 12**B, the above noted process may be repeated for producing the contactor by forming two or more conductive layers. Namely, after forming a first layer of the contactors, if necessary, the processes of **FIGS. 13D-13G** are repeated to form a second layer or further layers on the first layer of the contactors.

[0073] In the next process, the photoresist layer **548** is removed in a resist stripping process as shown in **FIG. 13H**. In **FIG. 13I**, the conductive substrate **546** is peeled from the chrome-inconel layer **544** on the substrate **540**. The conductive substrate **546** is a thin substrate on which the contactors **230** are mounted with a relatively weak adhesive strength. The top view of the conductive substrate **546** having the contactors **230** is shown in **FIG. 13J**.

[0074] **FIG. 13K** shows a process in which an adhesive tape **90** is placed on an upper surface of the contactors **230**. The adhesive strength between the adhesive tape **90** and the contactors **230** is greater than that between the contactors **230** and the conductive substrate **546**. Thus, when the adhesive tape **90** is removed from the conductive substrate **546**, the contactors **230** are transferred from the conductive substrate **546** to the adhesive tape **90** as shown in **FIG. 13L**. **FIG. 13M** shows a top view of the adhesive tape **90** having the contactors **230** thereon and **FIG. 13N** is a cross sectional view of the adhesive tape **90** having the contactors **230** thereon.

[0075] As has been foregoing, according to the present invention, the probe contact system has a simple structure by

eliminating many components used in the conventional technology. Namely, by incorporating the flexible printed circuit board, the probe contact system of the present invention is established without using the pogo-pin block, pogo-pins, coaxial cables, probe card and space transformer in the conventional technology. The flexible printed circuit board has signal patterns and works as a space transformer by changing pitches of the contactors to the pitches of the socket in the test head. The flexible printed circuit board works as signal cables for connecting the contactors with the test head, thereby obviating the probe card, pogo-pins and coaxial cables in the conventional technology.

[0076] The probe contact system of the present invention has a broad bandwidth covering high frequency region to meet the test requirements of next generation semiconductor technology. Since a large number of contactors are produced at the same time on a substrate trough a semiconductor production process, it is possible to achieve consistent quality, high reliability and long life in the contactor performance as well as low cost. Further, according to the present invention, the production process is able to produce a large number of contactors in a horizontal direction on the silicon substrate by using relatively simple technique. Such contactors are mounted on a contactor carrier in a vertical direction. The probe contact system in the present invention is low cost, and has high efficiency, high mechanical strength and reliability.

[0077] Although only a preferred embodiment is specifically illustrated and described herein, it will be appreciated that many modifications and variations of the present invention are possible in light of the above teachings and within the purview of the appended claims without departing the spirit and intended scope of the invention.

1. A probe contact system for establishing electrical connection between contact targets and a semiconductor test system, comprising:

a main frame having an opening on a bottom at about a center thereof;

a contactor carrier attached to the main frame, the contactor carrier mounting a plurality of contactors in a manner that lower ends of the contactors being projected from a lower surface of the contactor carrier through the opening of the main frame and top ends of the contactors being projected from an upper surface of the contactor carrier;

a flexible printed circuit board having contact pads at a center area thereof and signal lines connected to the contact pads and extended to an end of the flexible printed circuit board, the center area of said flexible printed circuit board being mounted on the contactor carrier in a manner that the top ends of the contactors contacting with the contact pads on the flexible printed circuit board;

wherein each of said contactors has a top spring for resiliently contacting the top end with the contact pad on the flexible printed circuit board, and wherein the end of said flexible printed circuit board with said signal lines is connected to a test head of the semiconductor test system;

wherein each of the contactors includes a stopper to position the contactor on the contactor carrier when the contactor is inserted in a through hole of the contactor carrier;

wherein said top spring of the contactor is provided between the top end and the stopper, and

wherein each of the contactors further comprises a main spring between a lower end and the stopper for producing a resilient contact force when the lower end is pressed against the contact target.

2. A probe contact system as defined in claim 1, further comprising a frame adaptor which is attached to the main frame to hold the flexible printed circuit board between the contactor carrier and the frame adaptor.

3. (canceled)

4. (canceled)

5. A probe contact system as defined in claim 1, wherein said top spring is formed of a diagonal beam and said main spring is formed of a plurality of zig-zag shaped spring elements.

6. A probe contact system as defined in claim 1, wherein said flexible printed circuit board has two ends extended from the center area and connected to the test head of the semiconductor test system.

7. A probe contact system as defined in claim 1, wherein said flexible printed circuit board has four ends extended from the center area and connected to the test head of the semiconductor test system.

8. A probe contact system as defined in claim 1, wherein a pitch between two signal lines on the flexible printed circuit board at the contact center area is smallest and is enlarged toward the end of the flexible printed circuit board.

9. (canceled)

10. A probe contact system for establishing electrical connection between contact targets and a semiconductor test system, comprising:

a main frame having an opening on a bottom at about a center thereof;

a contactor carrier attached to the main frame, the contactor carrier mounting a plurality of contactors in a manner that lower ends of the contactors being projected from a lower surface of the contactor carrier through the opening of the main frame and top ends of the contactors being projected from an upper surface of the contactor carrier;

a conductive elastomer sheet provided on the contactor carrier in a manner that the top ends of the contactors contact with a lower surface of the conductive elastomer sheet;

a flexible printed circuit board having contact pads at a center area thereof and signal lines connected to the contact pads and extended to an end of the flexible printed circuit board, the center area of said flexible printed circuit board being provided on the conductive elastomer sheet in a manner that an upper surface of the conductive elastomer sheet contacting with the contact pads on the flexible printed circuit board;

wherein the top end of the contactor is electrically connected to the contact pad on the flexible/printed circuit board through the conductive elastomer sheet, and wherein the end of said flexible printed circuit board

with said signal lines is connected to a test head of the semiconductor test system;

wherein each of the contactors includes a stopper to position the contactor on the contactor carrier when the contactor is inserted in a through hole of the contactor carrier; and

wherein each of the contactors further comprises a main spring between a lower end and the stopper for producing a resilient contact force when the lower end is pressed against the contact target.

11. A probe contact system as defined in claim 10, further comprising a frame adaptor which is attached to the main frame to hold the conductive elastomer sheet and the flexible printed circuit board between the contactor carrier and the frame adaptor.

12. A probe contact system as defined in claim 10, wherein the top end of the contactor has a thickness which is greater than that of other parts of the contactor.

13. (canceled)

14. (canceled)

15. A probe contact system as defined in claim 10, wherein said main spring is formed of a plurality of zig-zag shaped spring elements.

16. A probe contact system as defined in claim 10, wherein said flexible printed circuit board has two ends extended from the center area and connected to the test head of the semiconductor test system.

17. A probe contact system as defined in claim 10, wherein said flexible printed circuit board has four ends extended from the center area and connected to the test head of the semiconductor test system.

18. A probe contact system as defined in claim 10, wherein a pitch between two signal lines on the flexible printed circuit board at the contact center area is smallest and is enlarged toward the end of the flexible printed circuit board.

19. (canceled)

20. A probe contact system as defined in claim 10, wherein each of said conductive elastomer sheet is an elastic sheet with unidirectional conductivity by having a plurality of conductive wires in a direction vertical with the surface of the contactor carrier.

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