CONTACT STRUCTURE AND PRODUCTION METHOD THEREOF

Field of the Invention

This invention relates to a contact structure and its production method, and more particularly, to a contact structure having a large number of contactors in a vertical direction and to a method for producing such a large number of contactors on a semiconductor wafer in a horizonal direction and removing the contactors from the wafer to be mounted on a substrate in a vertical direction to form the contact structure such as a probe card, IC chip, or other contact mechanism in a vertical direction.

Background of the Invention

In testing high density and high speed electrical devices such as LSI and VLSI circuits, a high performance contact structure such as a probe card having a large number of contactors must be used. In other applications, contact structures may be used for IC packages as IC leads. The present invention is directed to a production process of such contact structures to be used in testing LSI and VLSI chips, semiconductor wafers, burn-in of semiconductor wafers and dice, testing and burn-in of packaged semiconductor devices, printed circuit boards and the like. The present invention can also be applicable to other purposes such as forming leads or terminal pins of IC chips, IC packages or other electronic devices. However, for the convenience of explanation, the present invention is described mainly with reference to the semiconductor wafer testing.

In the 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 a substrate handler, such as an automatic wafer prober, to automatically test the semiconductor wafer. Such an example is shown in Figure 1 in which a semiconductor test system 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 a substrate handler 400 are mechanically as well as electrically connected with one another 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.

On the test head 100, the semiconductor wafer to be tested is provided with test signals generated by the semiconductor test system. The resultant output signals from the semiconductor wafer under test (IC circuits formed on the semiconductor wafer) are transmitted to the semiconductor test system. In the semiconductor test system, the output signals are compared with expected data to determine whether the IC circuits on the semiconductor wafer function correctly.

In Figure 1, the test head 100 and the substrate handler 400 are connected through an interface component 140 consisting of a performance board 120 (shown in Figure 2) which is a printed circuit board having electric circuit connections unique to a test head's electrical footprint, coaxial cables, pogo-pins and connectors. In Figure 2, the test head 100 includes a large number of printed circuit boards 150 which correspond to the number of test channels (test 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. A "frog" ring 130 is mounted on the performance board 120 to accurately determine the contact position relative to the substrate handler 400. The frog ring 130 has a large number of contact pins 141, such as ZIF connectors or pogo-pins, connected to contact terminals 121, through coaxial cables 124.

As shown in Figure 2, the test head 100 is placed over the substrate handler 400 and mechanically and electrically connected to the substrate handler through the interface component 140. In the substrate handler 400, a semiconductor

wafer 300 to be tested is mounted on a chuck 180. In this example, a probe card 170 is provided above the semiconductor wafer 300 to be tested. The probe card 170 has a large number of probe contactors (such as cantilevers or needles) 190 to contact with contact targets such as circuit terminals or contact pads in the IC circuit on the semiconductor wafer 300 under test.

Electrical terminals or contact receptacles (contact pads) of the probe card 170 are electrically connected to the contact pins 141 provided on the frog ring 130. The contact 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 is connected to the printed circuit board 150 of the test head 100. Further, the printed circuit boards 150 are connected to the semiconductor test system through the cable 110 having, for example, several hundreds of inner cables.

Under this arrangement, the probe contactors 190 contact 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 wafer 300. The resultant output signals from the semiconductor 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 performs properly.

Figure 3 is a bottom view of the probe card 170 of Figure 2. In this example, the probe card 170 has an epoxy ring on which a plurality of probe contactors 190 called needles or cantilevers are mounted. When the chuck 180 mounting the semiconductor wafer 300 moves upward in Figure 2, the tips of the cantilevers 190 contact the pads or bumps (contact targets) on the wafer 300. The ends of the cantilevers 190 are connected to wires 194 which are further connected to transmission lines (not shown) formed in the probe card 170. The transmission lines are connected to a

plurality of electrodes (contact pads) 197 which are in communication with the pogo pins 141 of Figure 2.

Typically, the probe card 170 is structured by a multi-layer of polyimide substrates having ground planes, power planes, signal transmission lines on many layers. As is well known in the art, each of the signal transmission lines is designed to have a characteristic impedance such as 50 ohms by balancing the distributed parameters, i.e., dielectric constant and magnetic permeability of the polyimide, inductances and capacitances of the signal paths within the probe card 170. Thus, the signal lines are impedance matched lines establishing a high frequency transmission bandwidth to the wafer 300 for supplying currents in a steady state as well as high current peaks generated by the device's outputs switching in a transient state. For removing noise, capacitors 193 and 195 are provided on the probe card between the power and ground planes.

An equivalent circuit of the probe card 170 is shown in Figure 4 to explain the limitation of the high frequency performance in the conventional probe card technology. As shown in Figures 4A and 4B, the signal transmission line on the probe card 170 extends from the electrode 197, the strip (impedance matched) line 196, the wire 194 and the needle or cantilever (contact structure) 190. Since the wire 194 and needle 190 are not impedance matched, these portions function as an inductor L in the high frequency band as shown in Figure 4C. Because of the overall length of the wire 194 and needle 190 is around 20-30mm, significant limitations will be resulted from the inductor when testing a high frequency performance of a device under test.

Other factors which limit the frequency bandwidth in the probe card 170 reside in the power and ground needles shown in Figures 4D and 4E. If the power line can provide large enough currents to the device under test, it will not seriously limit the operational bandwidth in testing the device. However, because the series connected wire 194 and

needle 190 for supplying the power (Figure 4D) as well as the series connected wire 194 and needle 190 for grounding the power and signals (Figure 4E) are equivalent to inductors, the high speed current flow is seriously restricted.

Moreover, the capacitors 193 and 195 are provided between the power line and the ground line to secure a proper performance of the device under test by filtering out the noise or surge pulses on the power lines. The capacitors 193 have a relatively large value such as 10μF and can be disconnected from the power lines by switches if necessary. The capacitors 195 have a relatively small capacitance value such as 0.01μF and fixedly connected close to the DUT. These capacitors serve the function as high frequency decoupling on the power lines. In other words, the capacitors limit the high frequency performance of the probe contactor.

Accordingly, the most widely used probe contactors as noted above are limited to the frequency bandwidth of approximately 200MHz which is insufficient to test recent semiconductor devices. In the industry, it is considered that the frequency bandwidth comparable to the tester's capability, which is currently on the order of 1GHz or higher, will be necessary in the near future. Further, it is desired in the industry that a probe card is capable of handling a large number of semiconductor devices, especially memories, such as 32 or more, in a parallel fashion to increase test throughput.

In the conventional technology, the probe card and probe contactors such as shown in Figure 3 are manually made, resulting in inconsistent quality. Such inconsistent quality includes fluctuations of size, frequency bandwidth, contact forces and resistance, etc. In the conventional probe contactors, another factor making the contact performance unreliable is a temperature change under which the probe contactors and the semiconductor wafer under test have different temperature expansion ratios. Thus, under the varying temperature, the contact positions therebetween vary

which adversely affects the contact force, contact resistance and bandwidth. Thus, there is a need of a contact structure with a new concept which can satisfy the requirement in the next generation semiconductor test technology.

Summary of the Invention

Therefore, it is an object of the present invention to provide a contact structure having a large number of contactors for electrically contacting contact targets with a high frequency bandwidth, high pin counts and high contact performance as well as high reliability.

It is another object of the present invention to provide a contact structure such as a probe card to establish electrical connection for testing semiconductor devices and the like, having a very high frequency bandwidth to meet the test requirements in the next generation semiconductor test technology.

It is a further object of the present invention to provide a contact structure to establish electrical connection in applications such as testing semiconductor devices, which are suitable for testing a large number of semiconductor devices in parallel at the same time.

It is a further object of the present invention to provide a method for producing a large number of contactors by using relatively simple technique.

It is a further object of the present invention to provide a method for producing a large number of contactors in a two dimensional manner rather than a three dimensional manner on a planar surface of a silicon substrate.

It is a further object of the present invention to provide a method for producing a large number of contactors in a two dimensional manner on a silicon substrate, removing the contactors from the substrate and mounting the contactors on a contact substrate in a three dimensional manner to form a contact structure.

It is a further object of the present invention to provide a method for producing a large number of contactors

in a two dimensional manner on a silicon substrate, transferring the contactors to an adhesive tape and removing the contactors therefrom for vertically mounting them on a contact substrate to form a contact structure.

It is a further object of the present invention to provide a method for producing a large number of contactors with low cost and high efficiency and high reliability.

In the present invention, a contact structure for testing (including burn-in) a semiconductor wafers, packaged LSIs or printed circuit boards (devices under test) are formed of a large number of contactors produced on a planar surface of a silicon substrate by a photolithography technology established in the semiconductor production process. The contact structure of the present invention can also be used as components of electronics devices such as IC leads and pins.

The first aspect of the present invention is a contact structure for establishing electrical connection with contact targets. The contact structure is formed of a contact substrate and a plurality of contactors in which each of the contactors has a hook shape. The hook shape contactor is comprised of a tip portion which is protruded in a vertical direction to form a contact point, a base portion which is inserted in a through hole provided on the contact substrate in such a way that an end of the contactor functions as a contact pad for electrical connection at a bottom surface of the contact substrate, and a curved portion provided between the tip portion and the base portion which produces a contact force when the contactor is pressed against the contact target.

In another aspect of the contact structure of the present invention, the contact structure is formed of a contact substrate and a plurality of contactors in which each of the contactors has a loop shape. The loop shape contactor is comprised of a center portion which is protruded in a vertical direction to form a contact point, a base portion

having two ends which are inserted in through holes provided on the contact substrate in such a way that at least one end of the contactor is projected from a bottom surface of the contact substrate to function as a contact pad, a curved portion between the tip portion and the base portion to produce a contact force when the contactor is pressed against the contact target.

Another aspect of the present invention is a method of producing the contactors in a two dimensional manner on a silicon substrate and removing therefrom for establishing a contact structure. The production method is comprised of the following steps of:

(a) forming a sacrificial layer on a surface of a silicon substrate;

(b) forming an conductive layer made of electric conductive material on the sacrificial layer;

(c) forming a photoresist layer on the conductive layer;

(d) aligning a photo mask over the photoresist layer and exposing the photoresist layer with ultraviolet light through the photo mask, the photo mask including an image of the contactors;

(e) developing patterns of the image of the contactors on a surface of the photoresist layer;

(f) forming the contactors made of electric conductive material in the patterns on the photoresist layer by an electroplating process;

(g) stripping the photoresist layer;

(h) removing the sacrificial layer and the conductive layer by an etching process so that the contactors are separated from the silicon substrate; and

(i) mounting the contactors on a contact substrate having through holes to receive ends of the contactors therein so that at least one end of each of the contactors functions as a contact pad for electric connection.

A further aspect of the present invention is another method of producing the contactors in a two dimensional

manner on a silicon substrate and transferring the contactors to the adhesive tape and removing therefrom for establishing a contact structure. The production method is comprised of the following steps of:

(a) forming a sacrificial layer on a surface of a silicon substrate;

(b) forming an conductive layer made of electric conductive material on the sacrificial layer;

(c) forming a photoresist layer on the conductive layer;

(d) aligning a photo mask over the photoresist layer and exposing the photoresist layer with ultraviolet light through the photo mask, the photo mask including an image of the contactors;

(e) developing patterns of the image of the contactors on a surface of the photoresist layer;

(f) forming the contactors made of electric conductive material in the patterns on the photoresist layer by an electroplating process;

(g) stripping the photoresist layer;

(h) placing an adhesive tape on the contactors so that upper surfaces of the contactors adhere to the adhesive tape;

(i) removing the sacrificial layer and conductive layer by an etching process so that the contactors on the adhesive tape are separated from the silicon substrate; and

(j) mounting the contactors on a contact substrate having through holes to receive therein ends of the contactors wherein at least one end of each of the contactors function as a pad for electric connection.

A further aspect of the present invention is a method of producing the contactors in a two dimensional manner on a silicon substrate and transferring the contactors to the adhesive tape. The production method is comprised of the following steps of:

(a) forming an conductive substrate made of electric conductive material on a dielectric substrate;

(b) forming a photoresist layer on the conductive

substrate;

(c) aligning a photo mask over the photoresist layer and exposing the photoresist layer with ultraviolet light through the photo mask, the photo mask including an image of the contactors;

(d) developing patterns of the image of the contactors on a surface of the photoresist layer;

(e) forming the contactors made of electric conductive material in the patterns on the photoresist layer by an electroplating process;

(f) stripping off the photoresist layer;

(g) peeling the conductive substrate having contactors thereon from the dielectric substrate;

(h) placing an adhesive tape on the contactors on the conductive substrate so that upper surfaces of the contactors adhere to the adhesive tape wherein adhesive strength between the contactor and the adhesive tape is larger than that between the contactor and the conductive substrate;

(i) peeling the conductive substrate so that the contactors on the adhesive tape are separated from the conductive substrate; and

(j) mounting the contactor on a contact substrate having a through hole in such a way the an end of the contactor is projected from an opposite surface of the contact substrate.

A further aspect of the second present invention is a process of producing a contact structure having the above noted contactors with use of a pick and place mechanism. The production process is comprised of the following steps of:

(a) forming a sacrificial layer on a surface of a silicon substrate;

(b) forming an conductive layer made of electric conductive material on the sacrificial layer;

(c) forming the contactors through a photolithography process, the contact structures being in a horizontal directions on the silicon substrate;

(d) transferring the contactors from the silicon

substrate to an adhesive tape;

(e) positioning the adhesive tape having the contactors in a specified location;

(f) picking the contactor from the adhesive tape and orienting the contactor in a predetermined direction;

(g) positioning a contact substrate having through holes for receiving therein base portions of the contactors; and

(h) placing the contactors on predetermined positions of the contact substrate by inserting ends of the contactors in such a way that at least one end of each of the contactors functions as a contact pad for electrical connection.

According to the present invention, the contact structure has a very high frequency bandwidth to meet the test requirements of next generation semiconductor technology. Since the large number of contactors are produced at the same time on the substrate without involving manual handling, it is possible to achieve consistent quality, high reliability and long life in the contact performance as well as low cost. Further, because the contactors are assembled on the same substrate material as that of the device under test, it is possible to compensate positional errors caused by temperature changes.

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 produced are removed from the substrate and mounted on a contact substrate in a vertical direction. The contactors produced by the present invention are low cost and high efficiency and have high mechanical strength and reliability. The contact structure of the present invention is advantageously applied in testing a semiconductor wafer, packaged LSI, multi-chip module and the like including burn-in testing.

Brief Description of the Drawings

Figure 1 is a schematic diagram showing a structural

relationship between a substrate handler and a semiconductor test system having a test head.

Figure 2 is a diagram showing an example of a more detailed structure for connecting the test head of the semiconductor test system to the substrate handler through an interface component.

Figure 3 is a bottom view showing an example of the probe card having an epoxy ring for mounting a plurality of probe contactors (needles or cantilevers) in the conventional technology.

Figures 4A-4E are circuit diagrams showing equivalent circuits of the probe card of Figure 3.

Figure 5 is a schematic diagram showing an example of contact structure of the present invention using contactors produced in a horizontal direction on a surface of a silicon substrate where each of the contactor has a hook shape.

Figure 6 is a schematic diagram showing another example of contact structure of the present invention using contactors produced in a horizontal direction on a surface of a silicon substrate where each of the contactor has a loop shape.

Figures 7A-7D are schematic diagrams showing basic concepts of production method of the present invention in which a large number of contactors are formed on a planar surface of a silicon substrate and removed therefrom for later processes.

Figures 8A-8L are schematic diagrams showing an example of production process in the present invention for producing the contactors.

Figures 9A-9D are schematic diagrams showing another example of production process in the present invention for producing the contactors.

Figures 10A-10N are schematic diagrams showing a further example of production process in the present invention for producing the contactors.

Figures 11A and 11B are schematic diagrams showing an

example of pick and place mechanism and its process for picking the contactors and placing the same on a substrate such as a multi-layered silicon substrate to produce the contact structure of the present invention.

Figures 12 is a schematic diagram showing an example of contact structure of the present invention having a multi-layered silicon substrate and contactors produced through the production process of the present invention where each of the contactors has a hook shape.

Figures 13 is a schematic diagram showing an example of contact structure of the present invention having a multi-layered silicon substrate and contactors produced through the production process of the present invention where each of the contactors has a loop shape.

Figure 14 is a perspective view showing an example of contact structure of the present invention having a large number of contactors produced through the processes of the present invention.

Figure 15 is a cross sectional view showing an example of total stack-up structure using the contact structure of the present invention as an interface between a semiconductor device under test and a test head.

Detailed Description of the Preferred Embodiment

Figures 5 and 6 show examples of contact structure of the present invention. Each contact structure is configured by a contact substrate 20 and contactors 30. In the example of Figure 5, each contactor 30_1 has a hook shape and formed of a base portion which is connected to the contact substrate 20, a contact point which is preferably sharpened and oriented in a vertical direction, and a horizontally curved portion between the base portion and the contact point. In the example of Figure 6, each contactor 30_2 has a loop like shape and is formed of a base portion having two ends connected to the contact substrate 20, a loop like portion which is horizontally curved, and a contact point provided at the center of the loop like portion and protruded therefrom

in a vertical direction.

Each of the contactors 30 of Figures 5 and 6 produces contact pressure by a spring force derived mainly from the horizontally curved portion when the contact structure is pressed against contact pads 320 on the printed circuit board 300. The contact pressure also creates a scrubbing effect at the tip of the contactor against the surface of contact pad 320. Such a scrubbing effect promotes an improved contact performance when the contact point scrubs the oxide surface of the contact pad 320 to electrically contact the conductive material of the contact pad 320. It should be noted that, in the present invention, the contactors 30_1 and 30_2 are interchangeably used and produced although the contact structure and its production method will be described with respect to one of the contactors.

Figure 7A-7D show basic ideas of the present invention for producing such contactors. In the present invention, as shown in Figure 7A, contactors 30_2 are produced on a planar surface of a silicon substrate 40 or other dielectric substrate in a horizontal direction, i.e., in a two dimensional manner. Then, in the first example, as shown in Figure 7B, the contactors 30_2 are removed from the silicon substrate 40 to be mounted on a contact substrate 20 of Figure 6 such as a printed circuit board, IC chip, or other contact mechanism in a vertical direction, i.e., in a three dimensional manner.

In the second example, as shown in Figure 7C which is the same as Figure 7A, contactors 30_1 are produced on a planar surface of a silicon or other dielectric substrate 40 in a horizontal direction, i.e., in a two dimensional manner. Then, as shown in Figure 7D, the contactors 30_1 are transferred from the silicon substrate 40 to an adhesive member 90, such as an adhesive tape, adhesive film or adhesive plate (collectively "adhesive tape"). The contactors 30_1 on the adhesive tape are removed therefrom to be mounted on a contact substrate 20 of Figure 5 such as a

printed circuit board, IC chip, or other contact mechanism in a vertical direction, i.e., in a three dimensional manner with use of a pick and place mechanism.

Figures 8A-8L are schematic diagrams showing an example of production process for producing the contactor 30 (30_1 or 30_2) in the first example (Figure 7B) of the present invention where the adhesive tape 90 is not involved in the production process. In Figure 8A, a sacrificial layer 42 is formed on a substrate 40 which is typically a silicon substrate. Other dielectric substrate is also feasible such as a glass substrate. The sacrificial layer 42 is made, for example, of silicon dioxide (SiO_2) through a deposition process such as a chemical vapor deposition (CVD). The sacrificial layer 42 is to separate contactors 30 from the silicon substrate in the later stage of the production process.

An adhesion promoter layer 44 is formed on the sacrificial layer 42 as shown in Figure 8B through, for example, an evaporation process. An example of material for the adhesion promoter layer 44 includes chromium (Cr) and titanium (Ti) with a thickness of about 200-1,000 angstrom, for example. The adhesion promoter layer 44 is to facilitate the adhesion of conductive layer 46 of Figure 8C on the silicon substrate 40. The conductive layer 46 is made, for example, of copper (Cu) or nickel (Ni), with a thickness of about 1,000-5,000 angstrom, for example. The conductive layer 46 is to establish electrical conductivity for an electroplating process in the later stage.

In the next process, a photoresist layer 48 is formed on the conductive layer 46 over which a photo mask 50 is precisely aligned to be exposed with ultraviolet (UV) light as shown in Figure 8D. The photo mask 50 shows a two dimensional image of the contactor 30 which will be developed on the photoresist layer 48. 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 portions of the mask 50 harden (cure) after the exposure. Examples of photoresist material include Novolak (M-Cresol-formaldehyde), PMMA (Poly Methyl Methacrylate), SU-8 and photo sensitive polyimide. In the development process, the exposed part of the resist can be dissolved and washed away, leaving a photoresist layer 48 of Figure 8E having an opening or pattern "A". Thus, the top view of Figures 8F(1) and 8F(2) show the pattern or opening "A" on the photoresist layer 48 having the image (shape) of the contactor 30_1 or 30_2.

In the photolithography process in the foregoing, instead of the UV light, it is also possible to expose the photoresist layer 48 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 48 by exposing the photoresist 48 with a direct write electron beam, X-ray or light source (laser).

The contactor material such as copper (Cu), nickel (Ni), aluminum (Al), rhodium (Rh), palladium (Pd), tungsten (W) or other metal, nickel-cobalt (NiCo) or other alloy combinations thereof is deposited (electroplated) in the pattern "A" of the photoresist layer 48 to form the contactor 30 as shown in Figure 8G. Preferably, a contact material which is different from that of the conductive layer 46 should be used to differentiate etching characteristics from one another as will be described later. The over plated portion of the contactor 30 in Figure 8G is removed in the grinding (planarizing) process of Figure 8H.

In the next process, the photoresist layer 48 is removed in a resist stripping process as shown in Figure 8I. Typically, the resist layer 48 is removed by wet chemical processing. Other examples of stripping method include acetone-based stripping and plasma O_2 stripping. In Figure 8J, the sacrificial layer 42 is etched away so that the contactor 30 is separated from the silicon substrate 40. Another etching process is conducted so that the adhesion

promoter layer 44 and the conductive layer 46 are removed from the contactor 30 as shown in Figure 8K.

The etching condition can be selected to etch the layers 44 and 46 but not to etch the contactor 30. In other words, to etch the conductive layer 46 without etching the contactor 30, as noted above, the conductive material used for the contactor 30 must be different from the material of the conductive layer 46. Finally, the contactor 30 is separated from any other materials as shown in the perspective view of Figure 8L. Although the production process in Figures 8A-8L shows only one contactor 30, in an actual production process, as shown in Figures 7A-7D, a large number of contactors are produced at the same time.

Figures 9A-9D are schematic diagrams showing an example of production process for producing the contactors in the second example (Figure 7D) of the present invention. In the this example, an adhesive tape 90 is incorporated in the production process to transfer the contactors 30 from the silicon substrate 40 to the adhesive tape 90. Figures 9A-9D only show the latter part of the production process in which the adhesive tape 90 is involved.

Figure 9A shows a process which is equivalent to the process shown in Figure 8I where the photoresist layer 48 is removed in the resist stripping process. Then, also in Figure 9A, an adhesive tape 90 is placed on an upper surface of the contactor 30 so that the contactor 30 adheres to the adhesive tape 90. As noted above with reference to Figure 7D, within the context of the present invention, the adhesive tape 90 includes other types of adhesive member, such as an adhesive film and adhesive plate, and the like. The adhesive tape 90 also includes any member which attracts the contactor 30 such as a magnetic plate or tape, an electrically charged plate or tape, and the like.

In the process shown in Figure 9B, the sacrificial layer 42 is etched away so that the contactor 30 on the adhesive tape 90 is separated from the silicon substrate 40. Another

etching process is conducted so that the adhesion promoter layer 44 and the conductive layer 46 are removed from the contactor 30 as shown in Figure 9C.

As noted above, in order to etch the conductive layer 46 without etching the contactor 30, the conductive material used for the contactor 30 must be different from the material of the conductive layer. Although the production process in Figures 9A-9C shows only one contactor, in an actual production process, a large number of contactors are produced at the same time. Thus, a large number of contactors 30 are transferred to the adhesive tape 90 and separated from the silicon substrate and other materials as shown in the top view of Figure 9D.

Figures 10A-10N are schematic diagrams showing a further example of production process for producing the contactor 30_1 or 30_2 in the second example (Figure 7D) where the contactors are transferred to the adhesive tape. In Figure 10A, an electroplate seed (conductive) layer 342 is formed on a substrate 340 which is typically a silicon or glass substrate. The seed layer 342 is made, for example, of copper (Cu) or nickel (Ni), with a thickness of about 1,000-5,000 angstrom, for example. A chrome-inconel layer 344 is formed on the seed layer 342 as shown in Figure 10B through, for example, a sputtering process.

In the next process in Figure 10C, a conductive substrate 346 is formed on the chrome-inconel layer 344. The conductive substrate 346 is made, for example, of nickel-cobalt (NiCo) with a thickness of about 100-130μm. After passivating the conductive substrate 346, a photoresist layer 348 with a thickness of about 100-120μm is formed on the conductive substrate 346 in Figure 10D and a photo mask 350 is precisely aligned so that the photoresist layer 348 is exposed with ultraviolet (UV) light as shown in Figure 10E. The photo mask 350 shows a two dimensional image of the contactor 30 which will be developed on the surface of the photoresist layer 348.

In the development process, the exposed part of the resist can be dissolved and washed away, leaving a photoresist layer 348 of Figure 10F having a plating pattern transferred from the photo mask 350 having the image (shape) of the contactor 30 (30_1 and/or 30_2). In the step of Figure 10G, contactor material is electroplated in the plating pattern on the photoresist layer 348 with a thickness of about 50-60μm. An example of the conductive material is nickel-cobalt (NiCo). The nickel-cobalt contactor material will not strongly adhere to the conductive substrate 346 made of nickel-cobalt.

In the next process, the photoresist layer 348 is removed in a resist stripping process as shown in Figure 10H. In Figure 10I, the conductive substrate 346 is peeled from the chrome-inconel layer 344 on the substrate 340. The conductive substrate 346 is a thin substrate on which the contactors 30 are mounted with a relatively weak adhesive strength. The top view of the conductive substrate 346 having the contactors 30 is shown in Figure 10J.

Figure 10K shows a process in which an adhesive tape 90 is placed on an upper surface of the contactors 30. The adhesive strength between the adhesive tape 90 and the contactors 30 is greater than that between the contactors and the conductive substrate 346. Thus, when the adhesive tape 90 is removed from the conductive substrate 346, the contactors 30 are transferred from the substrate 346 to the adhesive tape 90 as shown in Figure 10L. Figure 10M shows a top view of the adhesive tape 90 having the contactors 30 thereon and Figure 10N is a cross sectional view of the adhesive tape 90 having the contactors 30 thereon.

Figures 11A and 11B are schematic diagrams showing an example of process for picking the contactors 30 from the adhesive tape 90 and placing the contactors on the contact substrate 20. The pick and place mechanism of Figures 11A and 11B is advantageously applied to the contactors produced by the production process of the present invention described

with reference to Figures 9A-9D and Figures 10A-10N involving the adhesive tape. Figure 11A is a front view of the pick and place mechanism 80 showing the first half process of the pick and place operation. Figure 11B is a front view of the pick and place mechanism 80 showing the second half process of the pick and place operation.

In this example, the pick and place mechanism 80 is comprised of a transfer mechanism 84 to pick and place the contactors 30, mobile arms 86 and 87 to allow movements of the transfer mechanism 84 in X, Y and Z directions, tables 81 and 82 whose positions are adjustable in X, Y and Z directions, and a monitor camera 78 having, for example, a CCD image sensor therein. The transfer mechanism 84 includes a suction arm 85 that performs suction (pick operation) and suction release (place operation) operations for the contactors 30. The suction force is created, for example, by a negative pressure such as vacuum. The suction arm 85 rotates in a predetermined angle such as 90 degrees.

In operation, the adhesive tape 90 having the contactors 30 and the contact substrate 20 having the bonding locations 32 (or through holes) are positioned on the respective tables 81 and 82 on the pick and place mechanism 80. As shown in Figure 11A, the transfer mechanism 80 picks the contactor 30 from the adhesive tape 90 by suction force of the suction arm 85. After picking the contactor 30, the suction arm 85 rotates by 90 degrees, for example, as shown in Figure 11B. Thus, the orientation of the contactor 30 is changed from the horizontal direction to the vertical direction. This orientation 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 80 then places the contactor 30 on the bonding location 32 (or through holes) on the substrate 20. The contactor 30 is attached to the contact substrate 20 by being bonded to the surface or inserted in the through holes.

Figure 12 is a cross sectional view showing an example

of contact structure of the present invention using the contactors 30_1 produced through the process such as Figures 8A-8L, 9A-9D or 10A-10N. The contactor 30_1 having the hook shape is attached to the contact substrate 20 in a manner that an end of the contactor 30_1 is inserted in a through hole 25. In this example, the contact substrate 20 is a multi-layered substrate having three standard silicon wafers 20_1, 20_2 and 20_3 which are stacked and fusion bonded to one another. An example of thickness of each of the silicon wafers 20_1-20_3 is about 0.5mm. The end of the contactor 30_1 is projected from the bottom surface of the contact substrate 20 for forming a contact pad 35. As an example, the size of the contact pad 35 is 0.5mm in width. The contactor 30_1 has a flange like portion 35 to be fitted with a step in the through hole 25. A contact point 31_1 at the tip of the contactor 30_1 is preferably sharpened to promote the scrubbing effect on the surface of the contact target.

Figure 13 is a cross sectional view showing an example of contact structure of the present invention using the contactors 30_2 produced through the process such as Figures 8A-8L, 9A-9D or 10A-10N. The contactor 30_2 having the loop shape is attached to the contact substrate 20 in a manner that both ends of the contactor 30_2 are inserted in through holes 25. Both ends or at least one end of the contactor 30_2 is projected from the bottom surface of the contact substrate 20 for forming contact pads 35. As an example, the size of the contact pad 35 is 0.5mm in width. The contactor 30_2 has a flange like portion 35 to be fitted with a step provided in the through hole 25. A contact point 31_2 at the top center of the contactor 30_2 is preferably sharpened to promote the scrubbing effect on the surface of the contact target. The contact substrate 20 has the same structure as that shown in Figure 12.

The process of forming three layered substrate 20 and through holes thereon shown in Figures 12 and 13 is briefly explained in the following. First, the second wafer 20_2 and

the third wafer 20_3 are directly bonded through, for example, silicon fusion bonding. Then the wafers 20_2 and 20_3 are polished both front and back, and through holes are created therethrough by an etching process. Such a deep trench etching is achieved, for example, by reactive ion etching using a reactive gas plasma. As shown in Figures 12 and 13, the size of the through holes on the second and third wafers 20_2 and 20_3 is smaller than the flange like portion 35 of the contactor 30 to form the steps in the through holes.

Then, the first wafer 20_1 is polished its front and back surfaces and through holes 25 are created therethrough by the deep trench etching noted above. The size of the through holes of the first wafer 20_1 is larger than that of the second and third wafers 20_2 and 20_3 to receive the flange like portion 35 of the contactor 30 as noted above. The first wafer 20_1 is aligned and fusion bonded to the second and third wafers 20_2 and 20_3. For insulation, silicon oxide layers of, for example, at least one micrometer is grown on all of the exposed surfaces of the contact substrate produced in this manner. Then, the contactor 30 is inserted in the through holes 25 and fixed therein by an adhesive.

Figure 14 is a perspective view showing an example of contact structure of the present invention having a large number of contactors 30 produced through the process shown in Figures 8A-8L, 9A-9D or 10A-10N and assembled in the manner shown in Figure 13. This example shows a plurality of contactors 30_2 assembled in a single line, however, a contact structure of the present invention may include contactors aligned in two or more lines, i.e, a matrix manner.

Figure 15 is a cross sectional view showing an example of total stack-up structure using the contact structure of the present invention as an interface between a device under test (DUT) and a test head such as shown in Figure 2. In this example, the interface assembly includes a conductive elastomer 250, a routing board (probe card) 260, and a pogo-pin block (frog ring) 130 provided over the contact structure

in the order shown in Figure 15.

The conductive elastomer 250, routing board 260 and pogo-pin block 130 are mechanically as well as electronically connected with one another. Thus, electrical paths are created from the contact point 31 of the contactors 30 to the test head 100 through the cables 124 and performance board 120 (Figure 2). Thus, when the semiconductor wafer 300 and the interface assembly are pressed with each other, electrical communication will be established between the DUT (contact pads 320 on the wafer 300) and the test system.

The pogo-pin block (frog ring) 130 is equivalent to the one shown in Figure 2 having a large number of pogo-pins to interface between the routing board 260 and the performance board 120. At upper ends of the pogo-pins, cables 124 such as coaxial cables are connected to transmit signals to printed circuit boards (pin electronics cards) 150 in the test head 100 in Figure 2 through the performance board 120. The routing board 260 has a large number of electrodes 262 and 265 on the upper and lower surfaces thereof. The electrodes 262 and 265 are connected through interconnect traces 263 to fan-out the pitch of the contact structure to meet the pitch of the pogo-pins in the pogo-pin block 130.

The conductive elastomer 250 is provided between the contact structure and the routing board (probe card) 260. The conductive elastomer 250 is to ensure electrical communications between the contact pads 35 of the contactors 30_1 and the electrodes 262 of the probe card by compensating planarization variance or vertical gaps therebetween. The conductive elastomer 250 is an elastic sheet having a large number of conductive wires in a vertical direction. For example, the conductive elastomer 250 is comprised of a silicon rubber sheet and a multiple rows of metal filaments. The metal filaments (wires) are provided in the vertical direction of Figure 15, i.e., orthogonal to the horizontal sheet of the conductive elastomer 250. An example of pitch between the metal filaments is 0.05mm with thickness of the

silicon rubber sheet is 0.2mm. Such a conductive elastomer is produced by Shin-Etsu Polymer Co. Ltd, Japan, and available in the market.

According to the present invention, the contact structure has a very high frequency bandwidth to meet the test requirements of next generation semiconductor technology. Since the large number of contactors are produced at the same time on the substrate without involving manual handling, it is possible to achieve consistent quality, high reliability and long life in the contact performance. Further, because the contactors are assembled on the same substrate material as that of the device under test, it is possible to compensate positional errors caused by temperature changes. Further, it is possible to produce a large number of contactors in a horizontal direction on the silicon substrate by using relatively simple technique. Such contactors are removed from the substrate and mounted on a contact substrate to form a contact structure such as a probe card in a vertical direction. The contact structure produced by the present invention is low cost and high efficiency and has high mechanical strength and reliability. The contact structure produced by the method of the present invention are advantageously applied in testing a semiconductor wafer, packaged LSI, multi-chip module and the like including burn-in testing.

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.

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WHAT IS CLAIMED IS:

1. A contact structure for establishing electrical connection with contact targets, comprising:

a contact substrate having through holes; and

a plurality of contactors where each of the contactors has a hook shape and is comprised of a tip portion which is protruded in a vertical direction to form a contact point, a base portion which is inserted in a through hole provided on the contact substrate in such a way that an end of the contactor functions as a contact pad for electrical connection at a bottom surface of the contact substrate, and a curved portion provided between the tip portion and the base portion which produces a contact force when the contactor is pressed against the contact target;

wherein the end of the contactor is inserted in a through hole of the contact substrate to be projected from the bottom surface thereof to function as a contact pad for electrical communication with an external component.

2. A contact structure for establishing electrical connection with contact targets as defined in Claim 1, wherein the contact substrate is formed of a plurality of silicon wafers bonded to one another and the through holes on the contact substrate are created through an etching process.

3. A contact structure for establishing electrical connection with contact targets as defined in Claim 1, wherein each of the contactors is provided with a flange like shape at the bottom portion thereof to be fitted in the through holes on the contact substrate.

4. A contact structure for establishing electrical connection with contact targets as defined in Claim 1, wherein the contact substrate is formed of first, second and third silicon wafers, wherein the second and third silicon wafers are fusion bonded and a second through hole is created therethrough by an etching process, and a first through hole

which is larger than the second through hole is produced on the first silicon wafer, and wherein the first silicon wafer is aligned to match positions of the through holes and fusion bonded to the second silicon wafer.

5. A contact structure for establishing electrical connection with contact targets, comprising:

a contact substrate having through holes; and

a plurality of contactors where each of the contactors has a loop shape and is comprised of a center portion which is protruded in a vertical direction to form a contact point, a base portion having two ends, and a loop portion between the center portion and the base portion which is horizontally curved to produce a contact force when the contactor is pressed against a contact target;

wherein the two ends of the contactor are inserted in through holes provided on the contact substrate in such a way that at least one end of the contactor is projected from a bottom surface of the contact substrate to function as a contact pad for electrical communication with an external component.

6. A contact structure for establishing electrical connection with contact targets as defined in Claim 5, wherein the contact substrate is formed of a plurality of silicon wafers bonded to one another and the through holes on the contact substrate are created through an etching process.

7. A contact structure for establishing electrical connection with contact targets as defined in Claim 5, wherein each of the contactors is provided with a flange like shape at the bottom portion thereof to be fitted in the through holes on the contact substrate.

8. A contact structure for establishing electrical connection with contact targets as defined in Claim 5, wherein the contact substrate is formed of first, second and third silicon wafers, wherein the second and third silicon wafers are fusion bonded and a second through hole is created

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therethrough by an etching process, and a first through hole which is larger than the second through hole is produced on the first silicon wafer, and wherein the first silicon wafer is aligned to match positions of the through holes and fusion bonded to the second silicon wafer.

9. A method for producing a contact structure, comprising the following steps of:

forming a sacrificial layer on a surface of a silicon substrate;

forming an conductive layer made of electric conductive material on the sacrificial layer;

forming a photoresist layer on the conductive layer;

aligning a photo mask over the photoresist layer and exposing the photoresist layer with ultraviolet light through the photo mask, the photo mask including an image of the contactors;

developing patterns of the image of the contactors on a surface of the photoresist layer;

forming the contactors made of electric conductive material in the patterns on the photoresist layer by an electroplating process, each of the contactors having either a hook shape with a semi-circular spring portion or a loop shape with a circular spring portion;

stripping the photoresist layer;

removing the sacrificial layer and the conductive layer by an etching process so that the contactors are separated from the silicon substrate; and

mounting the contactors on a contact substrate having through holes to receive ends of the contactors therein so that at least one end of each of the contactors functions as a contact pad for electric connection.

10. A method for producing a contact structure as defined in Claim 9, in the aligning and exposing step, the photoresist layer is exposed by an electron beam or X-rays

through the photo mask.

11. A method for producing a contact structure as defined in Claim 9, in the aligning and exposing step, the photoresist layer is directly exposed by an electron beam, X-ray or laser light to define the image of the contactor thereon.

12. A method for producing a contact structure as defined in Claim 9, further including a step of forming an adhesion promoter layer between the sacrificial layer and the conductive layer.

13. A method for producing a contact structure as defined in Claim 9, wherein the electric conductive material for the conductive layer is different from the electric conductive material for the contactors.

14. A method for producing a contact structure, comprising the following steps of:

forming a sacrificial layer on a surface of a silicon substrate;

forming an conductive layer made of electric conductive material on the sacrificial layer;

forming a photoresist layer on the conductive layer;

aligning a photo mask over the photoresist layer and exposing the photoresist layer with ultraviolet light through the photo mask, the photo mask including an image of the contactors;

developing patterns of the image of the contactors on a surface of the photoresist layer;

forming the contactors made of electric conductive material in the patterns on the photoresist layer by an electroplating process, each of the contactors having either a hook shape with a semi-circular spring portion or a loop shape with a circular spring portion;

stripping the photoresist layer;

placing an adhesive tape on the contactors so that upper surfaces of the contactors adhere to the adhesive

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tape;

removing the sacrificial layer and conductive layer by an etching process so that the contactors on the adhesive tape are separated from the silicon substrate; and

mounting the contactors on a contact substrate having through holes to receive therein ends of the contactors wherein at least one end of each of the contactors function as a pad for electric connection.

15. A method for producing a contact structure as defined in Claim 14, in the aligning and exposing step, the photoresist layer is exposed by an electron beam or X-rays through the photo mask.

16. A method for producing a contact structure as defined in Claim 14, in the aligning and exposing step, the photoresist layer is directly exposed by an electron beam, X-ray or laser light to define the image of the contact structure thereon.

17. A method for producing a contact structure as defined in Claim 14, further including a step of forming an adhesion promoter layer between the sacrificial layer and the conductive layer.

18. A method for producing a contact structure as defined in Claim 14, wherein the sacrificial layer is made of silicon dioxide.

19. A method for producing contact structures as defined in Claim 14, wherein the electric conductive material for the conductive layer is different from the electric conductive material for the contactors.

20. A method for producing contact structures as defined in Claim 17, wherein the adhesion promoter layer is made of chromium (Cr) or titanium (Ti).

21. A method for producing a contact structure, comprising the following steps of:

(a) forming an conductive substrate made of electric conductive material on a dielectric substrate;

(b) forming a photoresist layer on the conductive substrate;

(c) aligning a photo mask over the photoresist layer and exposing the photoresist layer with ultraviolet light through the photo mask, the photo mask including an image of the contactors;

(d) developing patterns of the image of the contactors on a surface of the photoresist layer;

(e) forming the contactors made of electric conductive material in the patterns on the photoresist layer by an electroplating process, each of the contactors having either a hook shape with a semi-circular spring portion or a loop shape with a circular spring portion;

(f) stripping off the photoresist layer;

(g) peeling the conductive substrate having contactors thereon from the dielectric substrate;

(h) placing an adhesive tape on the contactors on the conductive substrate so that upper surfaces of the contactors adhere to the adhesive tape wherein adhesive strength between the contactors and the adhesive tape is larger than that between the contactors and the conductive substrate;

(i) peeling the conductive substrate so that the contactors on the adhesive tape are separated from the conductive substrate; and

(j) mounting the contactor on a contact substrate having a through hole in such a way the an end of the contactor is projected from an opposite surface of the contact substrate.

22. A method for producing a contact structure as defined in Claim 21, wherein the conductive substrate and the contactors are made of nickel-cobalt (NiCo).

23. A method for producing a contact structure as defined in Claim 21, further comprising a step of forming a chrome-inconel layer on the dielectric substrate where the conductive substrate is created on the chrome-inconel layer.

24. A method for producing a contact structure having contactors each of which is able to exhibit a spring force

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for establishing electrical contact with a contact target, comprising the following steps of:

forming a sacrificial layer on a surface of a silicon substrate;

forming an conductive layer made of electric conductive material on the sacrificial layer;

forming the contactors through a photolithography process, the contact structures being in a horizontal directions on the silicon substrate, each of the contactors having either a hook shape with a semi-circular spring portion or a loop shape with a circular spring portion;

transferring the contactors from the silicon substrate to an adhesive tape;

positioning the adhesive tape having the contactors in a predetermined location;

picking the contactor from the adhesive tape and orienting the contactor in a predetermined direction;

positioning a contact substrate having through holes for receiving therein base portions of the contactors; and

placing the contactors on predetermined positions of the contact substrate by inserting ends of the contactors in such a way that at least one end of each of the contactors functions as a contact pad for electrical connection.