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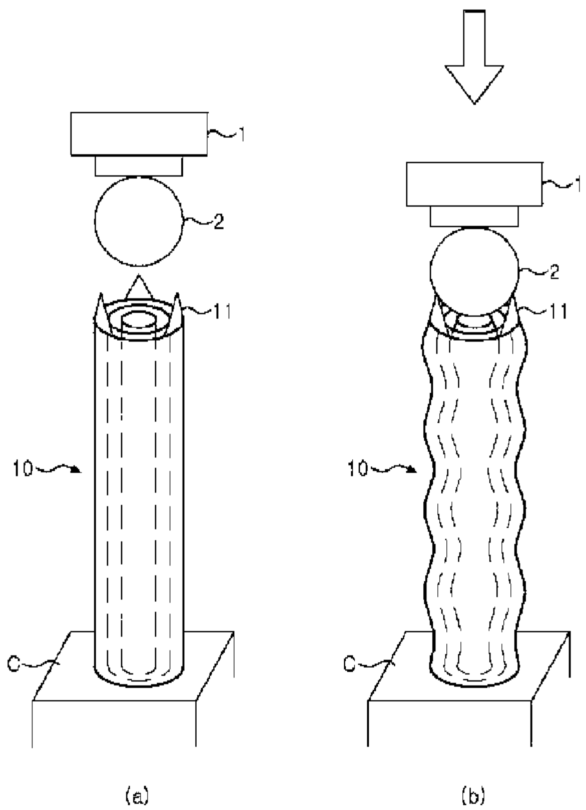
(54) Title: CONCENTRIC BUCKLING BASED VERTICAL PROBE AND ITS FABRICATION METHOD

[Fig. 2]



(57) Abstract: The present invention relates to a vertical probe and its fabrication method wherein the vertical probe is configured in a concentric pattern such that large elastic deformation can be made in a vertical direction and a simple fabrication process can also be performed. According to the present invention, there is provided a vertical probe for use in testing whether a semiconductor device normally operates by applying an electrical signal to the device, wherein one or more cylindrical structures are arranged in a concentric pattern and are subjected to concentric elastic buckling when longitudinal load is applied thereto.

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Description

CONCENTRIC BUCKLING BASED VERTICAL PROBE AND ITS FABRICATION METHOD

Technical Field

[1] The present invention relates to a vertical probe and its fabrication method, and more particularly, to a vertical probe and its fabrication method wherein the vertical probe is configured in a concentric pattern such that large elastic deformation can be made in a vertical direction and a simple fabrication process can also be performed.

Background Art

[2] In an integrated circuit (IC) manufacturing industry, devices are manufactured using a semiconductor wafer and are then tested to select normal devices among all the manufactured devices. The selected devices are packaged by Epoxy Molding Compound (EMC) and are then subjected to a series of tests before they are brought to the market.

[3] A variety of tests performed in the IC manufacturing industry are made in such a manner that a probe tip is brought into contact with an electrode pad electrically connected with a device to apply electrical signals to the device during a wafer level step, a device level step, a package level step, and so on. An operator can determine whether the device is normal through an electrical signal input to the device and the resultant output electrical signal.

[4] Various kinds of probes have been developed and categorized into many shapes such as a beam (or rod) type, a needle type or cantilever type, a spring type, a bleed type, a membrane type, and so on.

[5] A variety of references for the probe and a probe card including a plurality of probes are presented and some references related to the present invention are listed as follows.

[6] [1] Korea Patent Laid-Open Publication No. 10-2004-0003735 (Vertical probe card)

[7] [2] Korea Patent Laid-Open Publication No. 10-2005-0076508 (Vertical probe)

[8] [3] Korea Patent Laid-Open Publication No. 10-2006-0115570 (Vertical probe and its fabrication method)

[9] [4] U.S. Patent No. 6,404,211 (Metal buckling beam probe)

[10] [5] U.S. Publication No. 2006/0066328 (Buckling beam probe assembly)

[11] [6] U.S. Patent No. 6,529,021 (Self-scrub buckling beam probe)

[12] A widely used conventional needle type probe can be easily used in an electrode pad placed at an edge portion of an IC chip, but is very difficult to be used when a high density electrode pad exists in the form of an area type like a flip chip. Further, as shown in FIG. 1, a needle type probe 3 can be easily slid in an electrode pad 1 with solder balls 2 attached thereto, unlike in a flat electrode pad. Thus, there is a problem

in that an electrical connection is not well made. Accordingly, many vertical probes using a cantilever or tube as disclosed in the reference [1] ~ [6] have been developed.

[13] The biggest disadvantage of the vertical probe developed so far is that the vertical probe does not have sufficiently large over drive (OD). Unlike the needle type probe, the vertical probe has large hardness and is thus difficult to increase the OD due to its very small elastic deformation range.

[14] Accordingly, a method of increasing elastic deformation in a vertical direction using a curved beam like a spring as disclosed in references [2] and [5], a method of mounting a spring to a probe tip as disclosed in reference [3], a method of increasing elastic deformation by causing a straight beam to be buckled, and the like have been applied to the vertical probe.

[15] The method of mounting a spring directly to a probe tip is most advantageous in increasing the OD as disclosed in reference [3]. Here, this method is appropriate when an interval between probes, i.e. a pitch, is relatively large, but there is a limitation in that it cannot be applied to a high density electrode pad with very small pitch.

[16] The method of using a curved beam as disclosed in references [2] and [5] is not advantageous over the method of using a spring in view of OD, but it is advantageous in that it can be applied to a device with a smaller pitch. However, there is another problem in that such a probe cannot be fabricated through a general manufacturing process.

[17] In reference [4], there is disclosed a probe adapted to be buckled when a load is applied to an initially straight beam and a probe supporting structure. It is advantageous in that the probe and the supporting structure can be applied to a device with a small pitch, but it is also disadvantageous in that manufacturing costs are increased due to a very complex process of manufacturing a probe supporting structure.

Disclosure of Invention

Technical Problem

[18] Accordingly, the present invention is conceived to solve the aforementioned problems in the prior art. An object of the present invention is to provide a vertical probe and its fabrication method wherein the vertical probe can be applied to a device having a high density electrode pad, large elastic deformation can be made in a vertical direction, i.e. the vertical probe can have large over drive (OD), and a simple fabrication process can also be performed.

[19] In other words, the object of the present invention is to provide a vertical probe and its fabrication method wherein a pitch between probes is minimized such that the vertical probe can be applied to a high density electrode pad, large elastic deformation

can be made in a vertical direction, and a simple fabrication process can also be performed.

Technical Solution

[20] According to an aspect of the present invention for achieving the object, there is provided a vertical probe for use in testing whether a semiconductor device normally operates by applying an electrical signal to the device, wherein one or more cylindrical structures are arranged in a concentric pattern and are subjected to concentric elastic buckling when longitudinal load is applied thereto.

[21] The cylindrical structure may be a hollow cylinder, and a plurality of the hollow cylinders may be arranged in a concentric pattern with a regular gap between the adjacent cylinders.

[22] Each of the hollow cylinders may have a constant thickness. In particular, the hollow cylinder has a constant thickness along a longitudinal direction.

[23] The cylindrical structures may comprise an inner solid cylinder disposed at the center thereof, and an outer hollow cylinder arranged in a concentric pattern around the inner cylinder.

[24] The cylindrical structure may have a cross section of a spirally rolled shape.

[25] Preferably, one or more probe tips are formed at an end of the vertical probe.

[26] According to another aspect of the present invention, there is provided a method of fabricating a vertical probe for testing whether a semiconductor device normally operates by applying an electrical signal to the device, comprising the steps of (a) laminating a seed layer and a photoresist layer on a substrate; (b) forming a designed shape and arrangement of the probe on the photoresist layer through a lithographic process; (c) forming one or more cylindrical structures arranged in a concentric pattern to constitute the probe through a plating process and a chemical mechanical polishing process; and (d) removing the unnecessary photoresist layer.

[27] The method of the present invention may further comprise the step of, after step (c), repeating once or more times a step of laminating another seed layer and another photoresist layer and then performing a lithographic process, a plating process and a chemical mechanical polishing process to form a probe tip at an end of the cylindrical structure.

[28] According to a further aspect of the present invention, there is provided a method of fabricating a vertical probe for testing whether a semiconductor device normally operates by applying an electrical signal to the device, comprising the steps of fabricating a thin sheet; rolling the fabricated sheet into a spiral shape to form a cylindrical structure; and mounting the formed cylindrical structure onto a substrate.

[29] The method of the present invention may further comprise the step of attaching one

or more probe tips to an end of the cylindrical structure.

[30] As described above, the present invention uses concentric (axisymmetric) buckling occurring in a multi-wall cylindrical structure to solve the aforementioned objects.

[31] So far, most vertical probes have been designed or adapted to avoid the buckling, because deformation caused by the buckling may induce contact and interference between adjacent probes 3 as shown in FIG. 1. Then, when the buckling has occurred in a probe designed such that a buckling point is out of a probe operating range, severe plastic deformation or breakage has been frequently produced.

[32] The present invention is characterized by actively using the buckling. That is, in the present invention, many advantages caused by the buckling can be utilized by setting a buckling point to an initial point in a probe operation range and designing a probe to undergo elastic buckling. The biggest advantage of the buckling is that stiffness of a probe structure after buckling is greatly decreased as compared with stiffness of the probe structure before buckling.

[33] The probe has minimum load for sufficient electrical contact and is preferably designed to increase the OD as long as possible in a region not less than the minimum load. That is, the probe is necessary to have large stiffness from a point when load begins to be applied to the probe to a point when the applied load reaches the minimum load, and it is preferred that the probe do not have too much stiffness, i.e. can sufficiently secure the elastic OD, after the applied load reaches the minimum load.

[34] When a structure with large stiffness is subjected to large deformation, stress applied to the structure is greatly increased to result in plastic deformation. A probe is usually required to have a life span of at least 20,000 times, but it is difficult to maintain such a life span once the plastic deformation occurs.

[35] Since a vertical probe configured into a multi-wall cylindrical shape is designed such that elastic buckling, i.e. concentric (axisymmetric) buckling, occurs at a point before or after the applied load reaches the minimum load, elastic OD can be sufficiently obtained. Further, since the plastic deformation does not occur, the vertical probe can have long life span.

Advantageous Effects

[36] A vertical probe of the present invention can be used in a large scale integrated device with a small pitch between probes and can have a concentric (axisymmetric) buckling effect having large OD without self-contact or interference caused from the buckling. Incidentally, electrical resistance is also decreased by small fluctuation occurring at the instance of the buckling.

[37] Furthermore, an inexpensive and easy fabrication method is provided to reduce fabrication costs of the probes.

Brief Description of the Drawings

[38] The above and other objects, features and advantages of the present invention will become apparent from the following descriptions of preferred embodiments given in conjunction with the accompanying drawings, in which:

[39] FIG. 1 illustrates a conventional vertical probe, wherein (a) illustrates a shape of the vertical probe before buckling and (b) illustrates a shape of the vertical probe after buckling;

[40] FIG. 2 illustrates a vertical probe according to a first embodiment of the present invention, wherein (a) illustrates a shape of the probe before buckling and (b) illustrates a shape of the probe after buckling;

[41] FIG. 3 illustrates a vertical probe according to a second embodiment of the present invention, wherein (a) illustrates a shape of the probe before buckling and (b) illustrates a shape of the probe after buckling;

[42] FIG. 4 is sectional views illustrating a variety of cross sections of vertical probes according to the present invention;

[43] FIG. 5 is a view illustrating a method of fabricating the vertical probe according to the present invention; and

[44] FIG. 6 is a view illustrating a method of fabricating the vertical probe simultaneously while fabricating a probe tip at an end of the probe according to the present invention.

Best Mode for Carrying Out the Invention

[45] Hereinafter, preferred embodiments of a vertical probe and its fabrication method according to the present invention will be described in detail with reference to FIGS. 2 to 6. Throughout the drawings, like reference numerals are used to designate like elements.

[46] FIGS. 2 and 3 show vertical probes according to first and second embodiments of the present invention, respectively, wherein (a) illustrates a shape of the vertical probe before buckling and (b) illustrates a shape of the vertical probe after buckling. FIG. 4 is a sectional view illustrating a variety of cross sections of the vertical probes according to the present invention.

[47] FIGS. 5 and 6 are views illustrating a method of fabricating the vertical probe according to the present invention. In particular, FIG. 6 is a view illustrating a method of fabricating a probe tip on an end of the vertical probe simultaneously while fabricating the vertical probe.

[48] When compressive load is applied to a cylindrical structure, buckling generally occurs in the structure. A single wall cylindrical structure is generally buckled into a convex shape in one direction as shown in FIG. 1, unlike in the concentric buckling.

[49] A multi-wall cylindrical structure is subjected to the concentric buckling by means of

interaction between adjacent walls when longitudinal load is applied thereto as shown in FIGS. 2 and 3. A vertical probe of the present invention has a multi-wall cylindrical structure as shown in FIGS. 2 and 3.

[50] As illustrated in FIG. 2, a vertical probe 10 according to the first embodiment of the present invention has a triple-wall cylindrical structure. That is, the vertical probe 10 according to the first embodiment is formed into a concentric configuration in which three hollow cylinders are spaced apart from one another by an interval in a radial direction. The probe 10 is formed on a probe card C, and particularly, it is illustrated in FIG. 2 that a single probe 10 is formed on a probe card C. If desired, however, a plurality of probes may be arranged in a certain pattern on a single probe card C.

[51] The respective hollow cylinders of the probe 10 may have the same thickness as one another, but they may be designed to have different thickness from one another, if necessary. Further, although it has been illustrated in FIGS. 2 and 3 that the three hollow cylinders are provided, the number of cylinders provided in the present invention may be at least two. However, the present invention is not limited thereto.

[52] As illustrated in FIG. 3, a vertical probe 20 according to the second embodiment of the present invention has a double-wall cylindrical structure. However, the probe 20 of the second embodiment is different from the probe 10 of the first embodiment in that the probe 10 is formed with the three concentric hollow cylinders with approximately same thickness arranged in a longitudinal direction, whereas the probe 20 is formed with an inner solid cylinder 20a placed at the center thereof and an outer hollow cylinder 20b placed around the inner cylinder 20a.

[53] The probe 20 according to the second embodiment is also formed on a probe card C. Although it is illustrated in FIG. 3 that the four probes 20 are formed on the probe card C, at least one or more probes may be arranged in a certain pattern on a single probe card C.

[54] As illustrated in FIGS. 2 and 3, probe tips 11 and 21 are formed at ends of the probes 10 and 20, respectively. Each of the probe tips 11 and 21 may be formed into a triangular pyramid, a circular cone, a sphere and so on in order to easily come into electrical contact with a solder ball 2 or pad formed on a device 1.

[55] Further, at least one or more probe tips 11 or 21 may be formed at each of the ends of the probes 10 or 20. Depending on the number of the probe tips 11 and 21 formed, one-point contact, three-point contact, four-point contact or the like with the solder ball 2 or pad may be made.

[56] A method of attaching the probe tips 11 or 21 to the ends of the probes 10 or 20 may include a conventional method such as a soldering method. As described later with reference to FIG. 6, the probe tips may be integrally formed on the ends of the probes 10 or 20 in the process of fabricating the probes 10 or 20.

[57] Since the structure experiences a sudden change in stiffness at an instance when the probes 10 or 20 are buckled, a movement (in other word, small fluctuation) of the end of the probe in a direction perpendicular to a height direction of the probe is produced. Even though it is smaller than a conventional buckling into a convex shape in one direction, the small fluctuation is also produced in the concentric (axisymmetric) buckling according to the present invention. This small fluctuation serves to scratch an oxide film on a surface of the electrode pad or solder ball 2, and thus, it is advantageous in that an electric resistance between the probe end and the pad or solder ball 2 can be reduced.

[58] According to the present invention, it is advantageous to apply the multi-wall structure to a desired process since a cross section of the multi-wall structure can be designed in various forms as shown in FIG. 4. A cross section of the probe 10 according to the first embodiment of the present invention is shown in FIG. 4 (a), and a cross section of the probe 20 according to the second embodiment of the present invention is shown in FIG. 4 (b).

[59] A cross section of a probe 30 according to a third embodiment of the present invention is shown in FIG. 4 (c). The probe 30 according to the third embodiment of the present invention can be manufactured by rolling a very thin sheet into a spiral shape similar to a concentric pattern.

[60] Hereinafter, a method of fabricating the probes 10 and 20 according to the first and second embodiments of the present invention will be explained with reference to FIGS. 5 and 6. The vertical cylindrical probes 10 and 20 are easy to fabricate, and thus, there is an advantage in that their manufacturing costs are inexpensive.

[61] So far, many of vertical probes have been manufactured one by one and have been manually and individually arranged at a desired position on the probe card C. On the contrary, since the vertical probes 10 and 20 of the present invention arranged at a desired position on the probe card C can be fabricated through a batch process, it is very advantageous in the reduction of fabrication costs.

[62] In the method of fabricating the vertical probe according to the present invention, the vertical probe arranged on a desired region freely or in a regular pattern can be fabricated at one time by using a plating process and a lithographical process.

[63] As shown in FIG. 5, the method of fabricating the vertical probe according to the present invention is as follows. That is, a seed layer 41 and a photoresist layer 42 are laminated on a substrate S (FIG. 5 (a)), and a designed shape and arrangement of the probe is formed on the photoresist layer 42 through a lithographic process (FIG. 5 (b)). Then, the multi-wall cylindrical structure constituting the probe is formed through a plating process and a chemical mechanical polishing (CMP) process (FIG. 5(c)). Finally, the photoresist layer 42 is removed to complete the fabrication of the multi-

wall cylindrical probe 10 or 20.

[64] Although it is illustrated in FIG. 5 that only one probe 10 or 20 is formed on the substrate S, a plurality of probes arranged on the substrate can be formed all at once, if necessary, according to the present invention.

[65] Although it is often advantageous to increase a height of the probe, a thickness of plated layer, i.e. the height of the probe, is limited due to a level of the plating process. About a plating thickness of 0.1 mm is a current limit of the general plating process, and only a few plating company has a technology capable of plating the layer up to a thickness greater than the plating limit (i.e., about 0.3 mm). Accordingly, the aforementioned fabrication method is advantageous in that the probe height is not very high.

[66] It is often necessary to surface treat the plated film using a CMP process. A plating material, i.e. a probe material, should be selected in consideration of electrical conductivity, mechanical properties (e.g., a wide range of elasticity and large yield strength) and the like, and Ni or Ni-Co alloy is generally used. Since many studies on the copper plating process have been made, it is advantageous in the process development. However, the copper probe should be carefully designed and fabricated because of its poor mechanical properties.

[67] Since the thickness of each wall, a gap between the adjacent walls and the like of the multi-wall cylindrical probe according to the present invention have influence on the overall stiffness of the probe, buckling load, and stiffness after buckling, a proper dimensional design is necessary according to a desired specification. The specification of the probe may be changed in various ways according to objects (devices, wafers, packages and the like) which will be tested by the probe.

[68] In the method of fabricating the probe according to the present invention, the probe tip 11 or 21 may be first fabricated and then soldered to the probe 10 or 20. Alternatively, the probe tip 11 or 21 may be integrally formed with the probe 10 or 20, as shown in FIG. 6.

[69] In step of FIG. 6 (a) after step of FIG. 5 (c), the probe tip 11 or 21 may be formed at the end of the multi-wall vertical cylindrical probe 10 or 20 according to the present invention.

[70] In other words, a method of fabricating the vertical probe formed integrally with the probe tip according to the present invention is as follows. A seed layer 41 and a photoresist layer 42 are first laminated on a substrate S (FIG. 5 (a)), and the designed shape and arrangement of the probe is formed on the photoresist layer 42 through a lithographic process (FIG. 5 (b)). Then, the multi-wall cylindrical structure constituting the probe is formed through a plating process and a chemical mechanical polishing (CMP) process (FIG. 5(c)) process. Next, a second seed layer 43 and a second photoresist layer 44 are again formed and a lithographic process, a plating process and

a CMP process and the like are then performed. Repeatedly, a third seed layer 45 and a third photoresist layer 46 are formed and a lithographic process, a plating process, a CMP process and the like are performed to form the probe tip 11 or 21 at the end of the probe 10 or 20 (FIG. 6 (a) to (c)). Finally, the photoresist layers 42, 44 and 46, and the unnecessary seed layers 43 and 45 are removed to complete the fabrication of the multi-wall cylindrical probe 10 or 20 formed integrally with the probe tip 11 or 21.

[71] Meanwhile, as shown in FIG. 4 (c), the multi-wall cylindrical vertical probe 30 according to the third embodiment of the present invention may be fabricated by rolling a very thin sheet into a spiral shape. The vertical probe 30 so fabricated has a problem in that the respective probes should be individually attached to the probe card (i.e., a substrate) unlike in the fabricating method described with reference to FIGS. 5 and 6, but has the following advantages.

[72] That is, in the method according to the third embodiment of the present invention, the probe 30 with great height can be easily fabricated. While the height of the probe fabricated by the method shown in FIGS. 5 and 6 is restricted, the probe with a height of several millimeters can be easily fabricated in a case where a sheet is rolled into a vertical probe.

[73] Further, a variety of materials may be employed. Since a plating process is used for the fabrication method shown in FIGS. 5 and 6, only a material developed for a plating process can be employed in this fabrication method. However, so long as it can be formed into a sheet, any material, e.g. beryllium copper, may be used in the method of using the sheet. Since a material such as beryllium copper has a wide range of elasticity, it is widely used for a spring or needle type probe but is difficult to fabricate through a plating process. However, if a beryllium copper sheet is rolled into the probe 30 according to the third embodiment of the present invention, very excellent characteristics may be obtained.

[74] Further, a sheet material has an excellent mechanical property. Most materials are work-hardened when they are formed into sheets. Therefore, even though the probes are made of the same materials, a probe obtained by a rolling process has an excellent mechanical strength to that of a probe obtained by a plating process.

[75] The fabrication of the probe has been completed after attaching the structure (i.e., a probe tip), which is easy to electrical connect, to the end of the probe 30 fabricated through a sheet rolling process, as described above. Then, if the finished probes are arranged on desired positions, a probe card which can be employed in the actual tests for electrical components is completed.

[76] While the present invention has been illustrated and described in connection with the accompanying drawings and the preferred embodiments, the present invention is not limited thereto and is defined by the appended claims. Therefore, it will be understood

by those skilled in the art that various modifications and changes can be made thereto without departing from the spirit and scope of the invention defined by the appended claims.

Claims

[1] A vertical probe for use in testing whether a semiconductor device normally operates by applying an electrical signal to the device, wherein one or more cylindrical structures are arranged in a concentric pattern and are subjected to concentric elastic buckling when longitudinal load is applied thereto.

[2] The vertical probe as claimed in claim 1, wherein the cylindrical structure is a hollow cylinder and a plurality of the hollow cylinders are arranged in a concentric pattern with a gap between the adjacent cylinders.

[3] The vertical probe as claimed in claim 2, wherein each of the hollow cylinders has a constant thickness.

[4] The vertical probe as claimed in claim 1, wherein the cylindrical structures comprise an inner solid cylinder disposed at the center thereof, and an outer hollow cylinder arranged in a concentric pattern around the inner cylinder.

[5] The vertical probe as claimed in claim 1, wherein the cylindrical structure has a cross section of a spirally rolled shape.

[6] The vertical probes as claimed in any one of claims 1 to 5, wherein one or more probe tips are formed at an end of the vertical probe.

[7] A method of fabricating a vertical probe for testing whether a semiconductor device normally operates by applying an electrical signal to the device, comprising the steps of:
(a) laminating a seed layer and a photoresist layer on a substrate;
(b) forming a designed shape and arrangement of the probe on the photoresist layer through a lithographic process;
(c) forming one or more cylindrical structures arranged in a concentric pattern to constitute the probe through a plating process and a chemical mechanical polishing process; and
(d) removing the unnecessary photoresist layer.

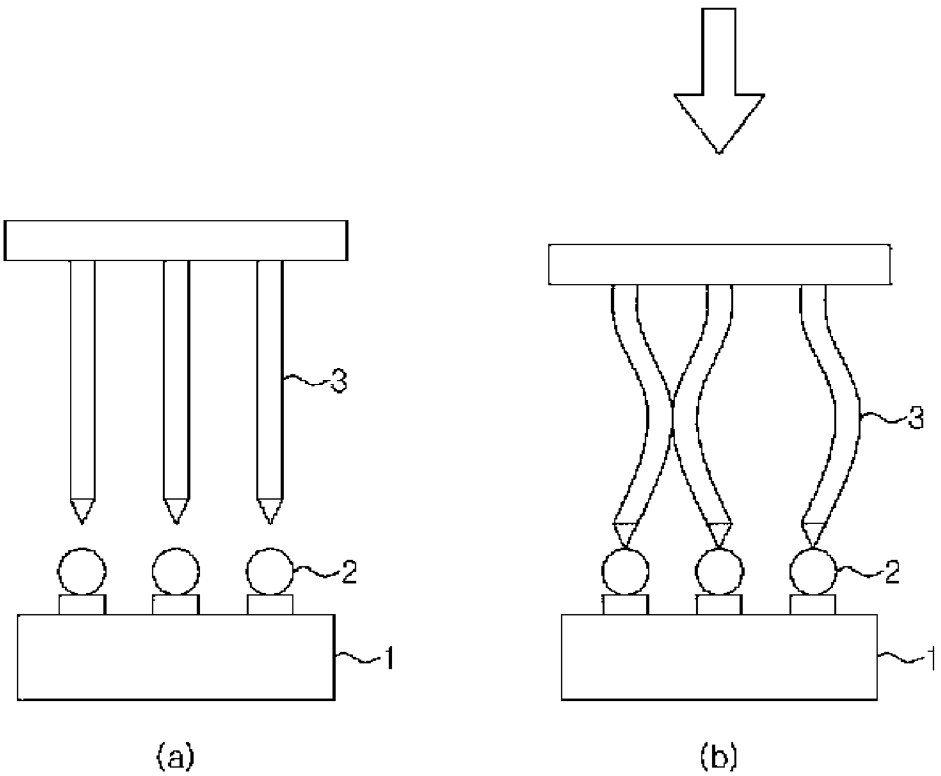
[8] The method as claimed in claim 7, further comprising the step of:
after step (c), repeating once or more times a step of laminating another seed layer and another photoresist layer and then performing a lithographic process, a plating process and a chemical mechanical polishing process to form a probe tip at an end of the cylindrical structure.

[9] A method of fabricating a vertical probe for testing whether a semiconductor device normally operates by applying an electrical signal to the device, comprising the steps of:
fabricating a thin sheet;
rolling the fabricated sheet into a spiral shape to form a cylindrical structure; and

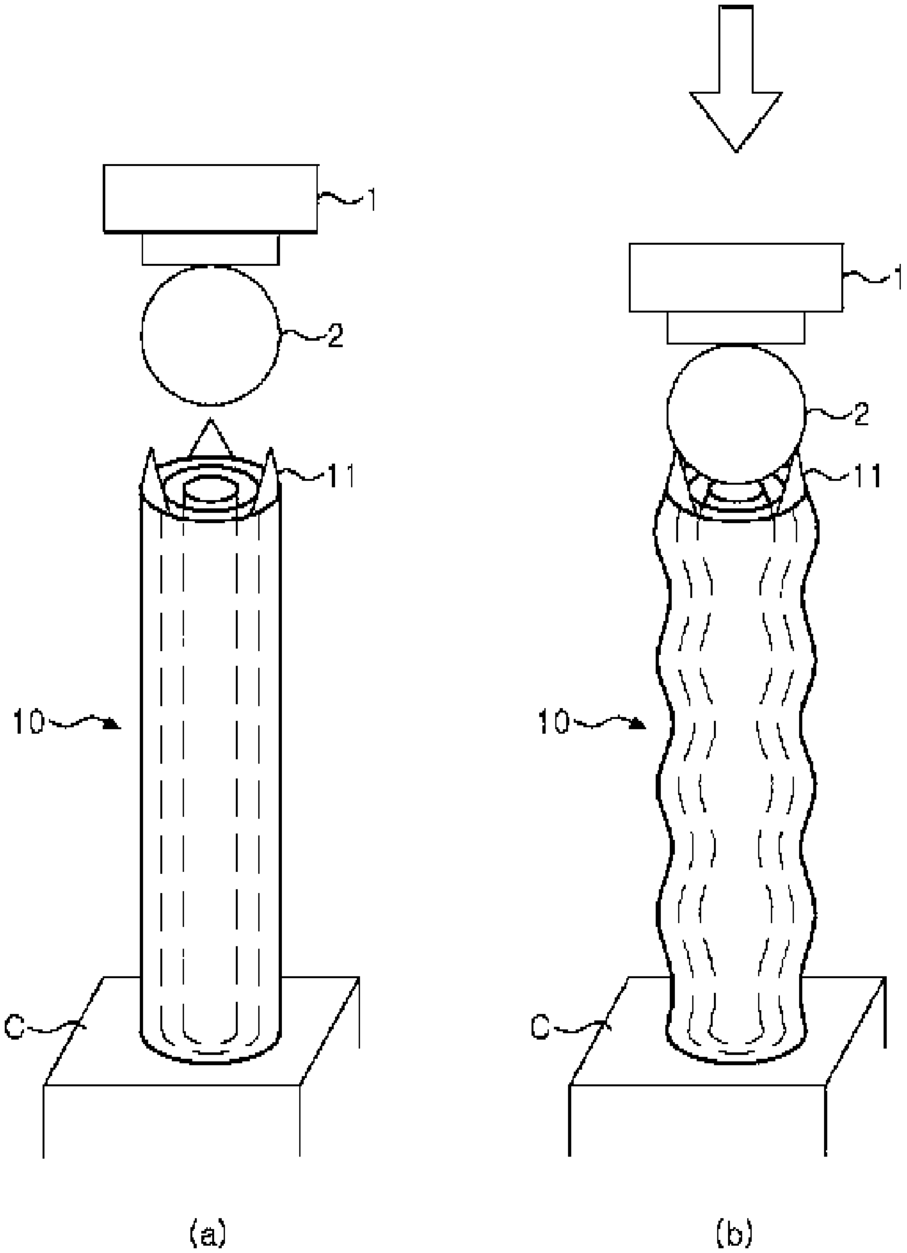
mounting the formed cylindrical structure onto a substrate.

[10] The method as claimed in claim 7 or 9, further comprising the step of: attaching one or more probe tips to an end of the cylindrical structure.

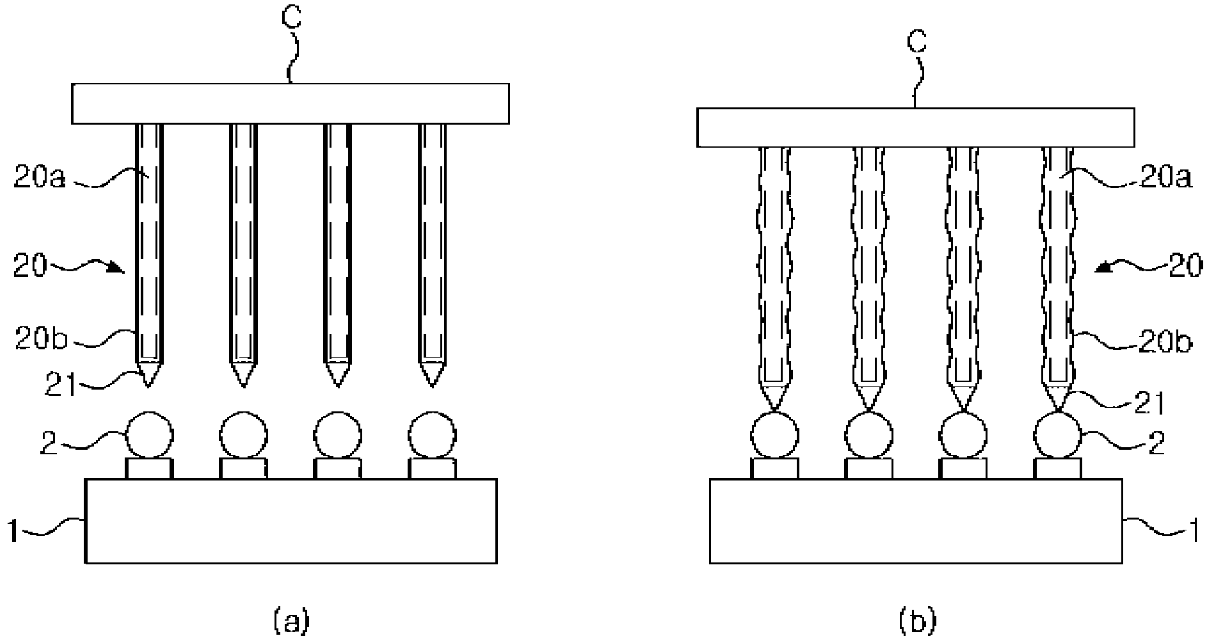
[Fig. 1]



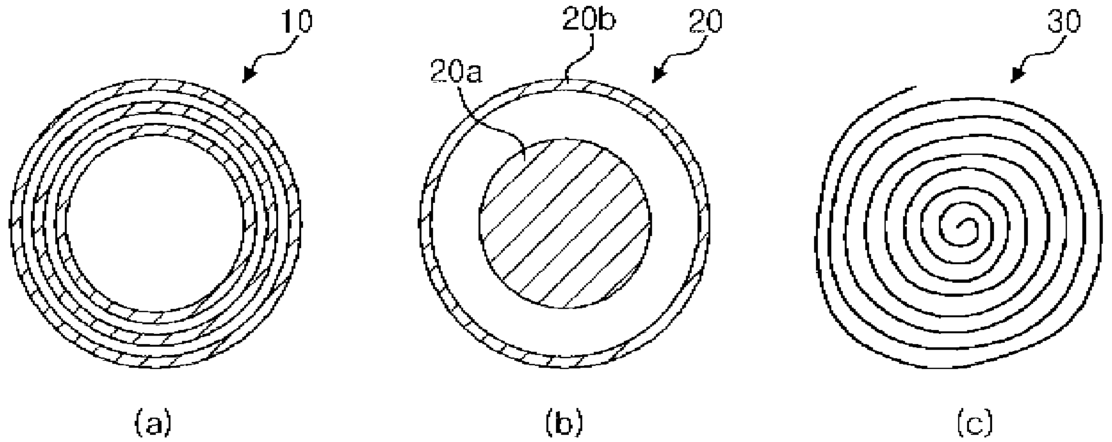
[Fig. 2]



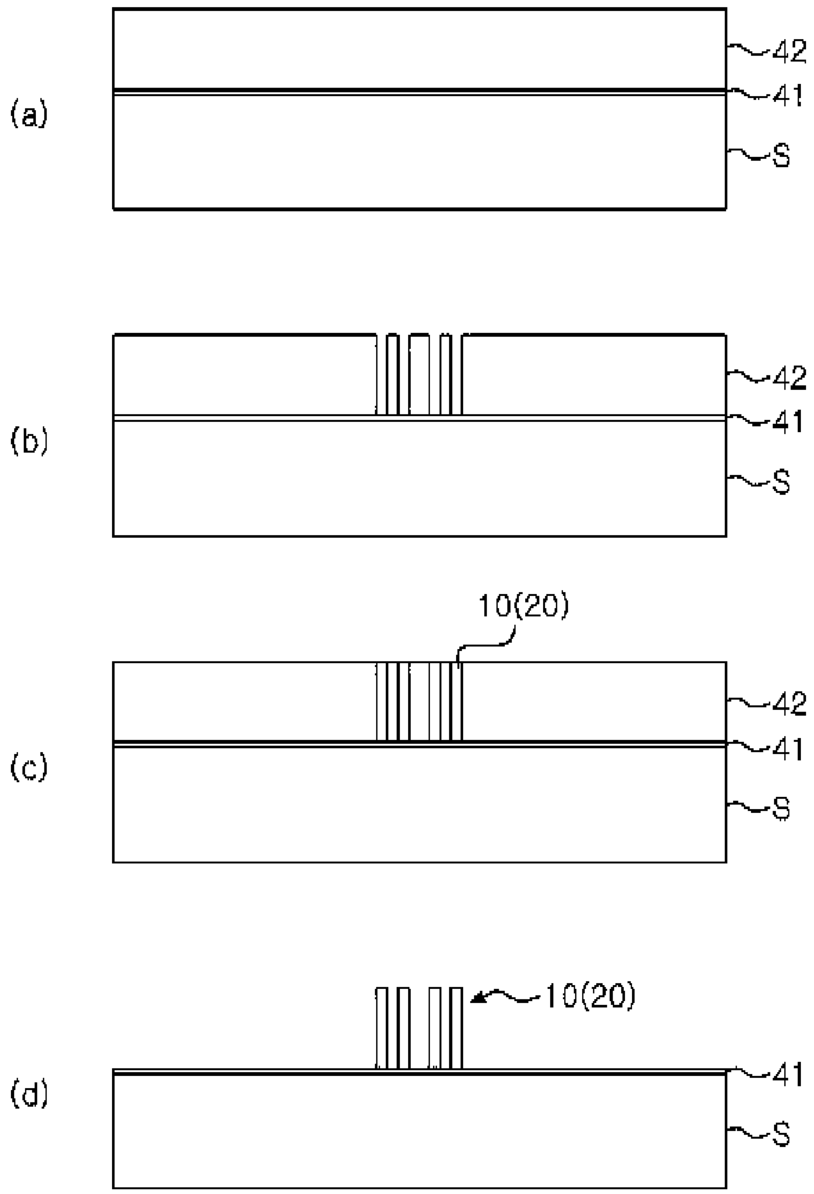
[Fig. 3]



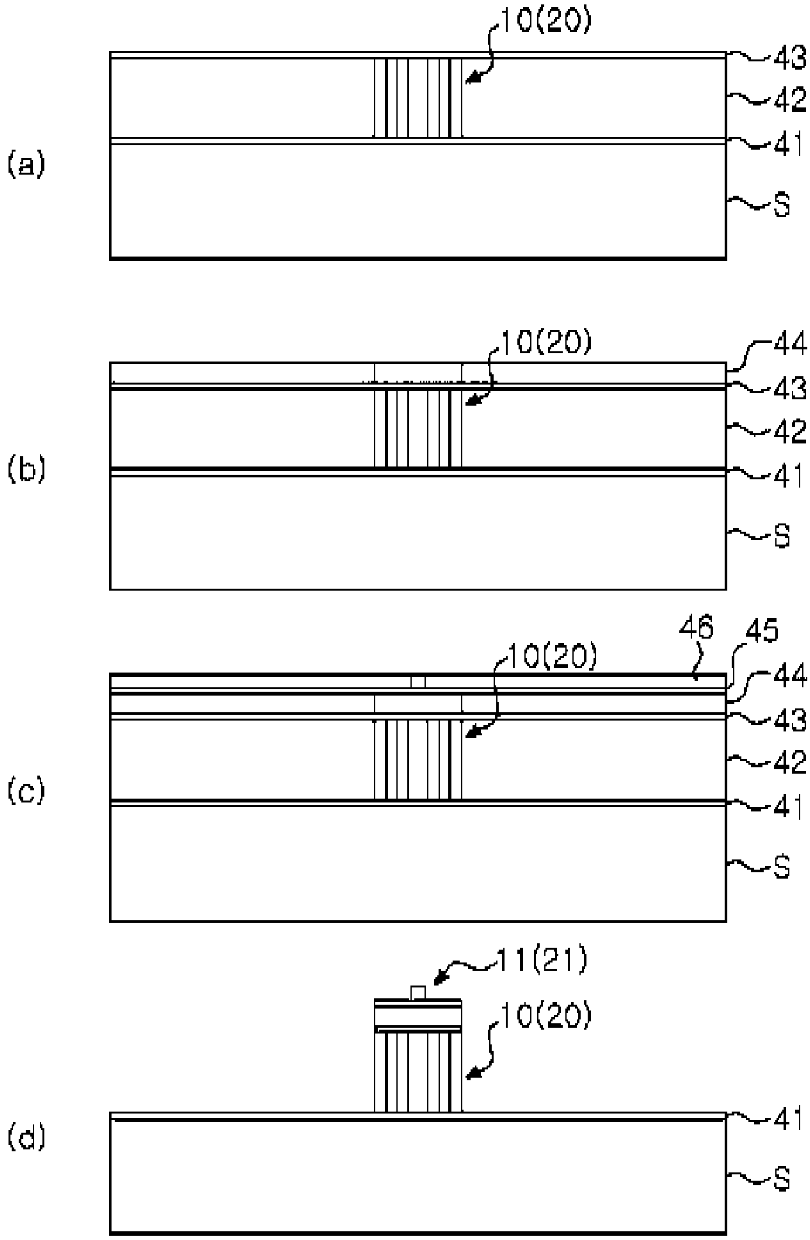
[Fig. 4]



[Fig. 5]



[Fig. 6]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