

[Document Name] SPECIFICATION

[Title of the Invention]

WINDING STRUCTURE OF BONDING WIRE FOR SEMICONDUCTOR DEVICES

[Technical Field]

[0001]

The present invention relates to a winding structure of a long bonding wire wound on a spool used, for example, to assemble a semiconductor device.

[Background Art]

[0002]

Bonding wires (hereinafter also referred to simply as "wires") used for connection between electrodes on semiconductor elements and external leads are mainly ultra-fine wires having a diameter of 15 to 75  $\mu\text{m}$  and made of a pure metal having a purity of 99.99 mass% or higher, such as gold, silver, or copper. In some cases, alloy wires of an Ag-Pd alloy, a noble metal-coated copper alloy, etc., are used. Such ultra-fine wires are shipped in a state in which they are each wound on a special spool for bonding wires in a laminated state with a trapezoidal cross-section, and the end of the wire is fixed to a flange by an adhesive tape. In the field of assembling semiconductor elements, the adhesive tape is removed from the bonding wire wound on the spool using tweezers, the wire end is held by the tweezers and passed through a bonding capillary, and the bonding wire is set in a semiconductor element assembling device.

[0003]

A spool for bonding wires generally has a cylindrical part (hereinafter also referred to as a "winding drum") having an outer diameter about 1/2 of an inch (12.7 mm) or about 2 inches (50.8 mm), and disk-shaped flanges fixed to both ends of the winding drum. As a modified spool for winding a longer semiconductor bonding wire, Japanese Patent Publication No. 2001-085462 proposes "a spool provided with inclined side surfaces inclined from both ends of the winding drum to the center."

[0004]

Various structures and methods have been proposed for the means for winding a bonding wire on the winding drum of such a spool.

For example, Japanese Utility Model Publication No. S59-187141 ("PTL 1," described later) discloses "a spool winding wire for semiconductor element bonding wires, having a cross-winding form in which a bonding wire is wound into the spool while a going-side winding wire and a returning-side winding wire are crossed, wherein the end portion of the winding wire is regularly wound on the peripheral surface of the spool in the vicinity of a flange," as shown in Fig. 1.

[0005]

Further, Japanese Examined Utility Model Publication No. S61-008049 ("PTL 2," described later) discloses "a metal wire feed package in which a fine metal wire is cross-wound in multilayers on a winding member, wherein the winding width of the metal wire is narrowed by 10 to 100 times the diameter of the metal wire at each of both ends of the winding width for every 100 to 700 layers." The Example of PTL 2 indicates that "the length of the wound gold wire was about 1,000 m." Moreover, Japanese Utility Model Publication No. S61-190135 discloses, "a bonding wire feed package in which a bonding wire is cross-wound in multilayers on a winding member, wherein the winding width of the wire is widened by 1 to 20 times the diameter of the wire at each of both ends of the winding width for every 10 to 100 layers." Furthermore, in response to the "demand for long winding wires (e.g., 500 to 5,000 m) in place of conventional 50- to 200-m winding wires," Japanese Examined Patent Publication No. H02-011017 ("PTL 3," described later) proposes "a bonding wire for semiconductor elements, wound on a spool comprising a single-layer winding part and a multilayer winding part continuing to the single-layer winding part, wherein the multilayer winding part has a multilayer structure in which regular-winding layers and 1 to 20 turns of cross-winding layers are alternately laminated."

[0006]

Moreover, Japanese Patent Publication No. S61-226466 discloses "a method for winding an ultra-fine wire, wherein when an ultra-fine wire is wound on a cylindrical spool, a winding start part of the ultrafine wire in contact with the outer peripheral surface of the spool is wound with a high tension, and then the tension is reduced to a predetermined value for winding." Similarly, Japanese Patent Publication No. H06-135632 discloses "a method for winding an ultra-fine wire, comprising supplying an ultra-fine wire from a supply spool on which the ultrafine wire is wound, and winding the supplied wire on a take-up spool, wherein a lead winding part, which is a winding start part, is wound with a predetermined first tension, a main winding part is wound with a predetermined second tension, and a tail winding part, which is a winding end part, is wound with plural tensions gradually changed from the second tension to a predetermined third tension."

[0007]

Furthermore, Japanese Patent Publication No. 2004-111449 ("PTL 4," described later) discloses "a winding structure of a bonding ultra-fine gold wire, in which an ultra-fine gold wire wound on a spool comprises a lead winding part in which the wire is regularly wound, a main winding part in which the wire is cross-wound in multilayers laminated in a bale-stacking form, and a tail winding part in which the wire is regularly wound, wherein the ultra-fine gold wire of the lead winding part is regularly wound in a state in which adjacent ultra-fine gold wires are in a close contact with each other."

[0008]

In these conventional winding structures of bonding wires, the winding wire comprising a main winding part laminated on a lead winding part has a trapezoidal cross-sectional shape, as shown in Fig. 1. A tension is applied by a tail winding part, in which the wire is regularly wound in a single-layer or multilayers, and which is provided beside the main winding part. When a tension is applied in this manner, vertical pressing

force acts on the entire cross-section of the main winding part due to the wire in the outermost peripheral layer. However, horizontal pressing force hardly acts on the wire in the outermost peripheral layer; therefore, although strong force acts on these wires, particularly the wire close to the outermost surface, the bonding wire is easily shifted due to vibration, etc., during transportation, and scratches tend to be formed on the bonding wire surface. The tendency of the formation of scratches was significant in wires of pure silver or a silver alloy having a low melting point. Therefore, pure silver or silver alloy bonding wires were limited to about 1,000-m winding.

[0009]

On the other hand, in the case of longer bonding wires not only for 2,000-m winding, but also for 10,000-m winding, the number of turns is increased, and it is necessary to further strengthen the tension of the wire in the outermost layer. However, when the slope of the oblique side of the main winding part is made steeper in order to increase the number of turns, the resistive force against lateral shift becomes relatively weak. Further, although the number of turns was increased, and the tension of the wire in the outermost layer was strengthened, the resistive force against lateral shift was still weak. In particular, pure silver wires are softer than copper wires and gold wires. Accordingly, pure silver wires had drawbacks in that they were susceptible to scratches, and the wire in the outermost layer could not be wound with a high tension. If the wire has scratches, molten balls may be unstable, and ultrasonic bonding may be unstable. When such a wire is used, continuous bonding operation is interrupted, thereby causing trouble. The tendency of the frequent formation of scratches was most often observed in bonding wires comprising a pure silver alloy having a low melting point (an alloy containing a metal component having an Ag purity of 99.99 mass% or more, and the balance of less than 0.01% of various additive elements). Moreover, relatively few scratches were observed in pure gold

wires, whereas relatively many scratches were observed in pure copper wires. Meanwhile, there was a problem in that when the number of turns was increased, collapse tended to occur during transportation.

[Citation List]

[Patent Literature]

[0010]

[PTL 1] Japanese Utility Model Publication No. S59-187141

[PTL 2] Japanese Examined Utility Model Publication No.

S61-008049

[PTL 3] Japanese Examined Patent Publication No. H02-011017

[PTL 4] Japanese Patent Publication No. 2004-111449

[Summary of Invention]

[Technical Problem]

[0011]

The present invention was made to solve the above problems, that is, the wire of the main winding part in which the wire is cross-wound in multilayers in a laminated state in a bale-stacking form is collapsed, and scratches, etc., are formed on pure silver alloy bonding wires and the like. An object of the present invention is to provide a novel winding structure of a bonding wire, the wire structure having a fastening force stronger than before, which does not collapse due to vibration, etc., during transportation. Another object of the present invention is to provide a winding structure of a bonding wire, the winding structure being configured such that a tail winding part is newly incorporated into the top of a main winding part, whereby waste of wire that does not contribute to bonding is saved, and spool replacement operation can be smoothly performed.

[Solution to Problem]

[0012]

The winding structure of the bonding wire of the present invention is a winding structure of a bonding wire wound on a spool comprising a lead winding part in which the wire is regularly wound, a main winding part in which the wire is

cross-wound in multilayers, and a tail winding part in which the wire is regularly wound; wherein

at least one of oblique sides of both end shapes of the main winding part has a protruding portion of an intermediate oblique side or an upper oblique side, the intermediate oblique side having an elevation angle steeper than the elevation angle of a lower oblique side extending from the end of the spool;

the protruding portion is continued to a wave-like zigzag layer; and

the height of the peak of the upper oblique side is higher than the average height of the zigzag layer.

[0013]

In the winding structure of the bonding wire of the present invention, the reason that at least one of oblique sides of both end shapes of the main winding part has a protruding portion of an intermediate oblique side or an upper oblique side, the intermediate oblique side having an elevation angle steeper than the elevation angle of a lower oblique side extending from the end of the spool, is because the protruding portion plays the role of the so-called barrier against lateral vibration. Because the height of the peak of the upper oblique side is higher than the average height of the zigzag layer, the pressing force of the protruding portion of the upper oblique side is horizontally dispersed, thereby suppressing the lateral vibration of the main winding part with an approximately rectangular cross-sectional shape. That is, even if the thickness of the main winding part is increased, the vertical pressing force from the tail winding part is not dispersed; thus, the main winding part with an approximately rectangular cross-sectional shape can be pressed with a pressing force of the protruding portion less than before.

[0014]

Moreover, the reason that the protruding portion is continued to a wave-like zigzag layer is because the horizontal resistive force acting on the wire due to vibration during transportation is dispersed. More specifically, this is to

prevent the wire of the main winding part cross-wound in multilayers from loosening. Triangular cross-sections formed by the zigzag layer may have a certain height because they are for dispersing the resistive force acting on the wire. In general, the height of all of the triangular cross-sections of the zigzag layer can be smaller than the height of the peak of the upper oblique side. Even when the triangular cross-sections are small, there is vertical pressing force in a narrow range corresponding to the base of each triangular cross-section, and the horizontal resistive force acting on the wire can be dispersed. Furthermore, since the wave-like zigzag layer also has vertical pressing force, the vertical pressing force of the protruding portion of the upper oblique side with respect to the horizontal resistive force acting on the wire can be relatively reduced.

[0015]

Preferred embodiments of the winding structure of the bonding wire of the present invention are as follows.

It is preferable that the protruding portion has a step-like shape. This is because when the main winding part has an elongated oblique side, collapse tends to occur due to lateral vibration. When the protruding portion has a step-like shape, the so-called barrier becomes large. Therefore, even if the thickness of the coating layer of the main winding part is increased, the winding structure of the bonding wire over the entire length thereof is less likely collapsed. Moreover, it is preferable that the cross-sectional area of the protruding portion is larger than the average cross-sectional area of the wave-like zigzag layer. This is because the protruding portion plays the role of the barrier against lateral vibration. That is, the height of the protruding portion can be increased, or the width thereof can be widened. This is because the pressing force of both end portions of the tail winding part in contact with the main winding part is strengthened to thereby prevent the wire of the main winding part from slipping. In an extreme case, the winding structure can consist of only the main winding

part, without providing the tail winding part or the lead winding part. This is because waste of wire is saved.

[0016]

It is also preferable that the protruding portion is provided in both ends of the main winding part. This is because when the end of the bonding wire is pinched with tweezers, the wire is hardly loosened. Another purpose thereof is to prevent lateral vibration.

[0017]

It is also preferable that the wave-like zigzag layer has 7 to 18 mountains. The mountains of the zigzag layer generally refer to a shape of wires piled in a triangular shape. However, the actual triangular shape is not symmetrical, and triangles formed by the wires have an uneven oblique side. Accordingly, for convenience, when the height of a reference wire, among wires continuing to the protruding portion of the upper oblique side in a projected plane, was higher than the height of both adjacent wires, it was counted as one mountain.

[0018]

It is also preferable that the bonding wire is a silver alloy. The reason for including not only pure silver alloys, but also silver alloys, is as follows. Specifically, this is because practical silver alloys, such as an Ag-Pd alloy, an Ag-Pd-Pt alloy, and an Ag-Pd-Au alloy, have a low melting point and are soft; therefore, their surface is susceptible to scratches, and the effects of the present invention are particularly significantly exhibited.

[0019]

It is also preferable that the bonding wire is a noble metal-coated copper alloy. The surface of noble metal-coated copper alloy wires is more susceptible to scratches than pure gold wires, and the effects of the present invention are exhibited. The noble metal-coated copper alloy wire as mentioned herein includes a Pd-coated pure copper alloy wire and an Au-dispersed Pd-coated pure copper alloy wire. This is because the surface of these wires is more susceptible to

scratches than pure gold wires, and the effects of the present invention are exhibited.

[0020]

In addition, the main winding part with a steeper elevation angle allows a longer wire to be wound; however, when the number of layers of the main winding part is increased, collapse tends to occur. Moreover, it is preferable that the mountains of the zigzag layer are formed in an area equal to or more than half the upper surface of the main winding part, and it is most preferable that the mountains are formed over the entire surface. The number of layers and the pitch interval in the main winding part are suitably determined, depending on the bonding device used.

[Advantageous Effects of Invention]

[0021]

According to the winding structure of the bonding wire of the present invention, a bonding wire longer than before, that is, a wire of the main winding part with an increased number of winding layers, can be firmly fixed with a tension of the tail winding part less than before. Moreover, the wave-like zigzag layer basically dispersedly suppresses the horizontal vibration of the wire of the main winding part; thus, the resistive force to vibration, etc., during transportation is stronger than before, and the vibration and swing of a wire longer than before can be prevented. Specifically, a bonding wire comprising a pure silver alloy or a silver alloy allows a long wire as long as 1,000 m or more to be tightly wound. A bonding wire comprising pure copper, a copper alloy, or Pd-coated Cu or copper alloy (the "Pd-coated copper" mentioned above) allows a long wire as long as 2,000 m or more to be tightly wound. A bonding wire comprising pure gold or a gold alloy allows a long wire as long as 5,000 m or more to be tightly wound. Furthermore, such a long wire wound in this manner is resistant to vibration and swing, and the surface of the bonding wire has no scratches, etc.; therefore, stable bonding operation can be continuously performed.

[0022]

Moreover, according to the present invention, a bonding wire longer than before can be supplied; therefore, a small number of times of rewinding the bonding wire is sufficient. Furthermore, since the wire of the tail winding part can also be used as a bonding wire, there is no waste of wire, and spool replacement operation can be continuously performed.

[Example 1]

[0023]

Using a wire having a diameter of 25  $\mu\text{m}$  and comprising pure silver (Ag) having a purity of 99.999 mass% or higher, 2,000 m of this wire was wound on a spool comprising a 2-inch (50.8-mm) cylindrical part and disk-shaped flanges, as shown in Fig. 2. Fig. 2 was drawn by a measuring microscope (OLYMPUS STM6) with a measuring magnification of 500 times. The horizontal axis represents the width direction of the spool, and the vertical axis represents the height direction of the spool. The height direction unit is about 60 times larger than the width direction.

[0024]

When the main winding part of Fig. 2 is viewed from right to left, a lower oblique side from the end of the spool becomes an upper oblique side at a point passing the half of a right oblique side to form a right protruding portion. The peak of the right protruding portion is the highest in the main winding part. Continuing from the right protruding portion, a wave-like zigzag layer comprising 10 large and small mountains is adjacent thereto. The zigzag layer is continued to a gentle left protruding portion. Although it is not shown, the end of the wire is fixed by a tape to the outer wall surface of the spool.

[0025]

Three spools on which the above bonding wire was wound were each placed in a spool case shown in Fig. 5, and dropped 5 times from a height of 30 cm above a desk; however, no collapse occurred. Thereafter, the appearance of the entire length of

the wire was examined by a stereomicroscope. As a result, no scratches were observed.

[Example 2]

[0026]

Using a bonding wire having a diameter of 18  $\mu\text{m}$  in which pure copper (Cu) having a purity of 99.99 mass% or higher was coated with a palladium (Pd) stretched layer, 2,000 m of this wire was wound on a spool comprising a 2-inch (50.8-mm) cylindrical part and disk-shaped flanges, as shown in Fig. 3.

[0027]

When the main winding part of Fig. 3 is viewed from right to left, a lower oblique side from the end of the spool is continued to a first flat region, and then continued to an intermediate oblique side that has an elevation angle steeper than the elevation angle of the lower oblique side. The intermediate oblique side is continued to a second flat region, and then continued to an upper oblique side. The highest peak of the upper oblique side is present to form a right protruding portion. Continuing from the right protruding portion, a wave-like zigzag layer comprising 8 large and small mountains is adjacent thereto.

[0028]

Three spools on which the above bonding wire was wound were each placed in a spool case shown in Fig. 5, and the same vibration test as in Example 1 was performed. Thereafter, the appearance of the entire length of the wire was examined by a stereomicroscope. As a result, no collapse occurred, and no scratches were observed.

[Example 3]

[0029]

Using a bonding wire having a diameter of 18  $\mu\text{m}$  in which pure copper (Cu) having a purity of 99.99 mass% or higher was coated with a palladium (Pd) thin stretched layer and a gold (Au) ultra-thin stretched layer, 2,000 m of this wire was wound on a spool comprising a 2-inch (50.8-mm) cylindrical part and disk-shaped flanges, as shown in Fig. 4.

[0030]

When the main winding part of Fig. 4 is viewed from right to left, a lower oblique side from the end of the spool becomes an upper oblique side at a point passing the half of a right oblique side to form a right protruding portion. The peak of the right protruding portion is the highest in the main winding part. Continuing from the right protruding portion, a wave-like zigzag layer comprising 12 large and small mountains is adjacent thereto.

[0031]

Three spools on which the above bonding wire was wound were each placed in a spool case shown in Fig. 5, and the same vibration test as in Example 1 was performed. Thereafter, the appearance of the entire length of the wire was examined by a stereomicroscope. As a result, no collapse occurred, and no scratches were observed.

[Conventional Example]

[0032]

Using the same wire as that of Example 1, 2,000 m of this wire was wound while making a lead winding part in which the wire was regularly wound, a main winding part in which the wire was cross-wound in multilayers, and a tail winding part in which the wire was regularly wound, independent from each other, as shown in Fig. 1.

[0033]

Three spools on which the above bonding wire was wound were each placed in a spool case shown in Fig. 5, and the same vibration test as in Example 1 was performed. As a result, the bonding wires slipped from all of the three spools, and they could not be mounted in a bonding device.

[Industrial Applicability]

[0034]

The winding structure of the bonding wire of the present invention is novel, and can be used for bonding wires applicable to various high-speed bonding machines for semiconductors, such as general ICs, discrete ICs, and memory ICs, as well as IC

package for LEDs, IC package for automobile semiconductors, etc., for which low cost is required in spite of high-humidity, high-temperature applications.

[Brief Description of Drawings]

[0035]

[Fig. 1] Fig. 1 is a drawing showing a conventional winding structure of a bonding wire.

[Fig. 2] Fig. 2 is an Example showing the winding structure of the bonding wire of the present invention.

[Fig. 3] Fig. 3 is another Example showing the winding structure of the bonding wire of the present invention.

[Fig. 4] Fig. 4 is another Example showing the winding structure of the bonding wire of the present invention.

[Fig. 5] Fig. 5 is a reference drawing showing a spool case for accommodating a bonding wire.

[Document Name] CLAIMS

[Claim 1]

A winding structure of a bonding wire wound on a spool comprising a lead winding part in which the wire is regularly wound, a main winding part in which the wire is cross-wound in multilayers, and a tail winding part in which the wire is regularly wound; wherein

at least one of oblique sides of both end shapes of the main winding part has a protruding portion of an intermediate oblique side or an upper oblique side, the intermediate oblique side having an elevation angle steeper than the elevation angle of a lower oblique side extending from the end of the spool;

the protruding portion is continued to a wave-like zigzag layer; and

the height of the peak of the upper oblique side is higher than the average height of the zigzag layer.

[Claim 2]

The winding structure of the bonding wire according to claim 1, wherein the protruding portion has a step-like shape.

[Claim 3]

The winding structure of the bonding wire according to claim 1, wherein the protruding portion is provided in both ends of the main winding part.

[Claim 4]

The winding structure of the bonding wire according to claim 1, wherein the wave-like zigzag layer has 7 to 18 mountains.

[Claim 5]

The winding structure of the bonding wire according to claim 1, wherein the bonding wire is a silver alloy.

[Claim 6]

The winding structure of the bonding wire according to claim 1, wherein the bonding wire is a noble metal-coated copper alloy.