

WIRE BONDING APPARATUS

[Technical Field]

[0001]

5 The present invention relates to a constitution of a bonding apparatus for bonding a wire to a bonding target.

[Background Art]

[0002]

10 A wire bonding apparatus for connecting an electrode of a semiconductor die and a lead of a lead frame to each other using a wire is often used. A wire bonding apparatus causes a capillary to perform ultrasonic vibration in a state in which a wire is pressed onto an electrode by the capillary, joins the wire and the electrode to each other, then lays the wire onto a lead, causes the capillary to perform ultrasonic vibration in a state in which the laid wire is pressed on the lead, and connects the wire and the lead to each other (for example, refer to Patent Literature 1).

15 [0003]

 In a wire bonding apparatus, a direction of ultrasonic vibration of a capillary corresponds to an extending direction of an ultrasonic horn (which will hereinafter be referred to as a Y direction). For this reason, a shape of a joint portion between a wire and an electrode or a joint portion between a wire and a lead exhibits a shape extending in the Y direction that is the
20 direction of ultrasonic vibration of a capillary, which may lead to poor joining.

[0004]

 Hence, a structure in which a part between an ultrasonic horn and an actuator of the ultrasonic horn is constituted of a flexible coupling frame that is elastically deformable and a capillary is caused to vibrate in a Y direction that is a vibration direction of the actuator and in an
25 X direction orthogonal to the Y direction has been proposed (for example, refer to Patent

Literature 2).

[Citation List]

[Patent Literature]

[0005]

5 [Patent Literature 1]

PCT International Publication No. WO2017/217385

[Patent Literature 2]

Japanese Patent No. 6073991

[Summary of Invention]

10 [Technical Problem]

[0006]

Incidentally, it is required that bonding be performed within a very short period of time such as approximately 10 msec. For this reason, it is required that a tip of a capillary be caused to vibrate in an X direction at a high frequency during bonding. In this regard, in the

15 constitution described in the cited Patent Literature 2, since a flexible coupling frame and an ultrasonic horn integrally vibrate in the X direction, a mass with respect to vibrations in the X direction becomes significant, and thus it is difficult to cause the ultrasonic horn to vibrate in the X direction at a high frequency. For this reason, when bonding is performed within a short period of time, the number of vibrations at the tip of the capillary during bonding is reduced,
20 which may lead to deterioration in bonding quality.

[0007]

Hence, an objective of the present invention is to improve the bonding quality of a wire bonding apparatus.

[Solution to Problem]

[0008]

According to the present invention, there is provided a wire bonding apparatus that includes an ultrasonic horn in which a bonding tool having a wire inserted therethrough is attached to a tip thereof and a bonding arm to which the ultrasonic horn is attached and which
5 performs bonding of the wire to a bonding target by bringing the bonding tool into contact with or separating the bonding tool from the bonding target. The wire bonding apparatus includes a wire clasper that has clamping arms protruding in a longitudinal direction from the bonding arm and clamping the wire, and a base body part attached to an upper side of the bonding arm and accommodating an actuator for performing an opening/closing operation of the clamping arms;
10 and a control unit that adjusts the opening/closing operation of the actuator of the wire clasper. The control unit causes the clamping arms to vibrate in an opening/closing direction in an open state using the actuator of the wire clasper during bonding.

[0009]

During bonding, light clamping arms can be caused to vibrate at a high frequency by
15 causing the clamping arms to vibrate in an X direction that is an opening direction. Further, high-frequency vibrations generated in the clamping arms are transferred to the tip of the ultrasonic horn so that the bonding tool can be caused to vibrate in the X direction at a high frequency during bonding. Accordingly, even when bonding is performed within a short period of time, the number of vibrations at the tip of the bonding tool in the X direction during bonding
20 can be increased, and thus the bonding quality can be improved.

[0010]

In the wire bonding apparatus of the present invention, the control unit may drive the clamping arms in the opening/closing direction at a frequency within a range of 80% to 120% of a resonant frequency of the clamping arms using the actuator of the wire clasper during

bonding.

[0011]

Accordingly, the clamping arms can be caused to significantly vibrate with a small input energy, and the bonding tool can be caused to sufficiently vibrate in the X direction during bonding. Accordingly, the bonding quality can be improved.

[0012]

In the wire bonding apparatus of the present invention, lengths of the clamping arms of the wire clasper may correspond to a length within a range of 80% to 120% of a length of the ultrasonic horn.

[0013]

Accordingly, the resonant frequency of the clamping arms in the X direction and the resonant frequency of the ultrasonic horn in the X direction become substantially the same frequency, and thus the ultrasonic horn resonates in the X direction in response to resonance of the clamping arms in the X direction. For this reason, vibrations due to resonance of the clamping arms are smoothly transferred to the ultrasonic horn, and thus a capillary attached to the tip of the ultrasonic horn can be caused to sufficiently vibrate in the X direction. Accordingly, the bonding quality can be improved.

[0014]

In the wire bonding apparatus of the present invention, in the wire clasper, the clamping arms may be in an open state when a predetermined open voltage is applied to the actuator and the clamping arms may be in a closed state when no voltage is applied to the actuator. The control unit may cause the clamping arms to vibrate in the opening/closing direction in an open state by applying a fluctuation voltage fluctuating within a predetermined voltage range centering on a base voltage that is the same as the predetermined open voltage or

slightly lower than the predetermined open voltage to the actuator. At this time, the base voltage may correspond to a voltage within a range of 80% to 100% of the predetermined open voltage. The predetermined voltage range may include a voltage within a range of 8% to 30% of the predetermined open voltage.

5 [0015]

Accordingly, the clamping arms can be caused to vibrate while maintaining an open state in which the clamping arms do not come into contact with the wire. For this reason, a vibration frequency of the clamping arms can be the resonant frequency or a frequency near the resonant frequency.

10 [0016]

The wire bonding apparatus of the present invention may include an ultrasonic vibrator that causes the ultrasonic horn to perform ultrasonic vibration in the longitudinal direction. The control unit may adjust driving of the ultrasonic vibrator, cause the clamping arms to vibrate in the opening/closing direction in an open state using the actuator of the wire clasper during bonding, and cause the ultrasonic horn to perform ultrasonic vibration in the longitudinal direction at the same time by causing the ultrasonic vibrator to perform ultrasonic vibration.

15 [0017]

According to this constitution, bonding can be performed in a state in which the tip of the bonding tool is caused to vibrate in an XY direction. Accordingly, a situation in which the shape of a joint portion of the wire exhibits a deformed shape extending in a Y direction and leads to poor joining can be curbed, and thus the bonding quality can be improved.

20 [Advantageous Effects of Invention]

[0018]

According to the present invention, the bonding quality of a wire bonding apparatus can

be improved.

[Brief Description of Drawings]

[0019]

Fig. 1 is a system diagram illustrating a side surface of a wire bonding apparatus of an
5 embodiment and a control system.

Fig. 2A is a bottom view illustrating a bonding arm and an ultrasonic horn of the wire bonding apparatus illustrated in Fig. 1.

Fig. 2B is a plan view illustrating the bonding arm and a wire clasper of the wire bonding apparatus illustrated in Fig. 1.

10 Fig. 3 is a graph illustrating a relationship between an applied voltage with respect to the wire clasper and an open dimension G at tips of clamping arms.

Fig. 4 is a plan view illustrating the open dimension G at the tips of the clamping arms when an applied voltage V illustrated in Fig. 3 is an open voltage V0, an applied voltage VB1, and an applied voltage VB2.

15 Fig. 5A is an elevation diagram illustrating a state of the ultrasonic horn and the wire clasper when a lower end of a wire is molded into a free air ball before bonding.

Fig. 5B is an elevation diagram illustrating a state of the ultrasonic horn and the wire clasper when the wire is bonded to a semiconductor element.

20 Fig. 5C is an elevation diagram illustrating a state of the ultrasonic horn and the wire clasper when the wire is bonded to a substrate.

Fig. 6A is a bottom view illustrating vibrations of the ultrasonic horn in the state illustrated in Figs. 5B and 5C.

Fig. 6B is a plan view illustrating vibrations of the clamping arms in the state illustrated in Figs. 5B and 5C.

[Description of Embodiment]

[0020]

Hereinafter, with reference to the drawings, a wire bonding apparatus 100 of an embodiment will be described. In the following description, description will be given while having an extending direction of an ultrasonic horn 10 and a bonding arm 20 or a longitudinal direction of the bonding arm 20 and the ultrasonic horn 10, that is, a direction from the bonding arm 20 to the ultrasonic horn 10 as a Y direction, an upward direction as a Z direction, and a direction orthogonal to the Y direction and the Z direction as an X direction. In addition, description will be given while having a positive side in the Y direction as a tip side, a negative side in the Y direction as a proximal side, the positive side in the Z direction as an upper side, a negative side in the Z direction as a lower side, the positive side in the X direction as a right side, and the negative side in the X direction as a left side.

[0021]

As illustrated in Fig. 1, the wire bonding apparatus 100 includes the ultrasonic horn 10, the bonding arm 20, a wire clammer 30, a control unit 60, and a bonding stage 51 holding a substrate 52 or a semiconductor element 53 (bonding target).

[0022]

As illustrated in Figs. 1 and 2A, the ultrasonic horn 10 includes a horn main body 11, a base part 12 formed on the negative side of the horn main body 11 in the Y direction (which will hereinafter be referred to as a proximal side), an opening 13 formed inside the base part 12, and an ultrasonic vibrator 16 accommodated inside the opening 13. The base part 12 includes a flange 14 protruding in the X direction. The flange 14 on the proximal side is attached to a positive side end 21 of the bonding arm 20 in the Y direction (which will hereinafter be referred to as a tip 21) using a bolt 15. A length from the flange 14 of the ultrasonic horn 10 fixed to the

tip 21 of the bonding arm 20 to a positive side end of the horn main body 11 in the Y direction is a length L_h . A capillary 41 serving as a bonding tool is attached to the positive side end of the horn main body 11 of the ultrasonic horn 10 in the Y direction. The capillary 41 is a cylindrical member having a sharp tip with a penetration hole at the center thereof. A wire 45 is inserted
5 through the center hole of the capillary 41.

[0023]

When the ultrasonic vibrator 16 performs ultrasonic vibration in the Y direction at a predetermined frequency, the horn main body 11 resonates in the Y direction, vertically vibrates, and causes the capillary 41 attached to the tip side of the horn main body 11 to vibrate in the Y
10 direction.

[0024]

As illustrated in Fig. 1, the bonding arm 20 is supported such that it can rotate in the direction indicated by the arrow 90 at a rotation center 26 disposed substantially at the same height as an upper surface of the substrate 52 or the semiconductor element 53. A Z-direction
15 motor 27 driving the capillary 41 connected to the tip of the ultrasonic horn 10 in the Z direction, and an XY driving mechanism 29 driving a base 28 having the Z-direction motor 27 mounted thereon in an XY direction are attached to a rear end part. In addition, a piezoelectric element 17 is attached to an upper surface of the bonding arm 20 on the tip side using a bolt 18. The piezoelectric element 17 detects a pressing force of the capillary 41 to the substrate 52 or the
20 semiconductor element 53.

[0025]

As illustrated in Figs. 1 and 2B, the wire clasper 30 is attached to an upper side of the bonding arm 20. The wire clasper 30 includes clamping arms 31 and a base body part 32. The base body part 32 is fixed to a portion on a seat 24 on the upper side of the bonding arm 20

using a bolt 25. The base body part 32 has a square opening 33 at the center thereof, and an actuator 34 is accommodated inside the opening 33. For example, the actuator 34 may be constituted of a piezoelectric element.

[0026]

5 Left and right arm attachment parts 36 extending toward the tip side are provided on the positive side of the base body part 32 in the Y direction. The clamping arms 31 are fixed to the arm attachment parts 36 using a bolt 35. Tips of the clamping arms 31 protrude in the Y direction from the tip 21 of the bonding arm 20 and clamp the wire 45. In addition, a recessed part 38 is provided between the left and right arm attachment parts 36. An elastic hinge 37
10 rotating around an axis in the Z direction is formed at a proximal part of the arm attachment part 36 from the recessed part 38. A length from the elastic hinge 37 to the tips of the clamping arms 31 is a length L_c . The length L_c corresponds to a length substantially similar to the length L_h from the flange 14 of the ultrasonic horn 10 fixed to the tip 21 of the bonding arm 20 to the positive side end of the horn main body 11 in the Y direction.

15 [0027]

Next, with reference to Figs. 3 and 4, a relationship between an applied voltage V with respect to the actuator 34 of the wire clasper 30 and an open dimension G of the clamping arms 31 will be described. As illustrated in Fig. 3, when a predetermined voltage is not applied to the actuator 34, the open dimension G of the clamping arms 31 becomes zero, and the wire
20 clasper 30 is in a closed state. At this time, when there is the wire 45 between the left and right clamping arms 31, the clamping arms 31 clamp the wire 45.

[0028]

If a predetermined open voltage V_0 is applied to the actuator 34, the clamping arms 31 rotate around the elastic hinge 37. As indicated by the solid line in Fig. 4, the tips of the

clamping arms 31 open in the X direction that is an opening/closing direction, and the open dimension G becomes a fully-open dimension G0. Since the fully-open dimension G0 is larger than a diameter d of the wire 45, the clamping arms 31 release the wire 45.

5 [0029]

As indicated by a solid line a in Fig. 3, the applied voltage V with respect to the actuator 34 and the open dimension G at the tips of the clamping arms 31 substantially have a proportional relationship. If the applied voltage V is increased, the open dimension G at the tips of the clamping arms 31 also increases in accordance therewith. As illustrated in Fig. 3, 10 when the applied voltage V is set to an applied voltage VB1 that is slightly lower than the open voltage V0, the open dimension G at the tips of the clamping arms 31 becomes a large open dimension G1 that is slightly smaller than the fully-open dimension G0 as in the clamping arms 31 indicated by the dashed line in Fig. 4. In addition, if the applied voltage V is set to an applied voltage VB2 that is lower than an applied voltage VB1, the open dimension G at the tips 15 of the clamping arms 31 becomes a small open dimension G2 that is smaller than the large open dimension G1 as in the clamping arms 31 indicated by the one-dot dashed line in Fig. 4. Since the small open dimension G2 is larger than the diameter d of the wire 45, even when the open dimension G at the tips of the clamping arms 31 becomes the small open dimension G2, the clamping arms 31 do not touch the wire 45, and the wire clasper 30 maintains an open state. 20 Therefore, if the applied voltage V is caused to fluctuate between the applied voltages VB1 and VB2, while the open state of the wire clasper 30 is maintained, the open dimension G at the tips of the clamping arms 31 can fluctuate in a dimension fluctuate range ΔG between the large open dimension G1 and the small open dimension G2. Here, in order to make the applied voltage V be a fluctuation voltage between the applied voltage VB1 and the applied voltage VB2, a median 25 value between the applied voltage VB1 and the applied voltage VB2 may be set to a base

voltage V_B , and the applied voltage V may be increased or decreased by a voltage range ΔV centering on the base voltage V_B . The base voltage V_B and the voltage range ΔV can be freely selected. For example, the base voltage V_B may be a voltage within a range of 80% to 100% of the open voltage V_0 , and the voltage range ΔV may be a voltage within a range of 8% to 30% of the open voltage V_0 .

[0030]

The control unit 60 includes a clamper control unit 61 and a bonding control unit 62. The clamper control unit 61 adjusts the applied voltage V of the actuator 34 of the wire clamper 30 and causes the clamping arms 31 to perform an opening/closing operation. The bonding control unit 62 adjusts the Z-direction motor 27 upon an input of a signal from the piezoelectric element 17 and drives a tip of the capillary 41 in a contact/separation direction with respect to the substrate 52 or the semiconductor element 53. In addition, the bonding control unit 62 controls the XY driving mechanism 29 such that the position of the capillary 41 in the XY direction is adjusted. In addition, the bonding control unit 62 causes the horn main body 11 to perform ultrasonic vibration in the Y direction by driving the ultrasonic vibrator 16 of the ultrasonic horn 10.

[0031]

Next, with reference to Figs. 5A to 5C, 6A, and 6B, bonding operation of the wire bonding apparatus 100 having the foregoing constitution will be described.

[0032]

As illustrated in Fig. 5A, the clamper control unit 61 sets the applied voltage V of the actuator 34 of the wire clamper 30 to zero and causes the wire clamper 30 to be in a closed state such that the wire clamper 30 clamps the wire 45. The bonding control unit 62 generates sparks between a torch electrode (not illustrated) and the wire 45 extending from the tip of the capillary 41 and molds a lower end of the wire 45 into a free air ball 50.

[0033]

As illustrated in Fig. 5B, the clamper control unit 61 performs vibrations at a frequency f_0 having the applied voltage V with respect to the actuator 34 of the wire clamper 30 within a range of the voltage range ΔV centering on the base voltage V_B illustrated in Fig. 3.

5 [0034]

Accordingly, vibrations are performed at the frequency f_0 having the applied voltage V with respect to the actuator 34 within a range of the applied voltage V_{B1} and an applied voltage V_{B2} illustrated in Fig. 3, and vibrations are performed at the frequency f_0 having the open dimension G at the tips of the clamping arms 31 between the large open dimension G_1 and the small open dimension G_2 as illustrated in Fig. 4. In this manner, the clamper control unit 61 causes the clamping arms 31 to vibrate at the frequency f_0 while the open state of the wire clamper 30 is maintained. Here, if the frequency f_0 is set to a frequency close to a resonant frequency f_1 at which the clamping arms 31 vibrate in the X direction, the clamping arms 31 laterally vibrate in the X direction centering on the elastic hinge 37 due to resonance as indicated by the arrow 96 in Fig. 6B. The frequency f_0 need only be a frequency close to the resonant frequency f_1 of vibrations of the clamping arms 31 in the X direction. When the resonant frequency of the clamping arms 31 is substantially 2 kHz, for example, the frequency f_0 may be a frequency near 2 kHz, for example, a frequency within a range of approximately 1.9 kHz to 2.0 kHz. Since the clamping arms 31 are light, they can sufficiently vibrate in the X direction even at such a high frequency. Accordingly, even when bonding is performed within a short period of time, the number of vibrations at the tip of the capillary 41 in the X direction during bonding can be increased. The frequency f_0 may be selected from a range such as $f_1/\sqrt{2} < f_0 < f_1 \times \sqrt{2}$, for example, as long as it is a frequency at which the clamping arms 31 resonate in the X direction or may be selected from frequencies within a range of 80% to 120% of the resonant frequency f_1

25

of the clamping arms 31 in the X direction.

[0035]

If the clamping arms 31 resonate, vibrations of the clamping arms 31 in the X direction
5 are transferred from the bonding arm 20 to the ultrasonic horn 10. Here, the length L_c from the
elastic hinge 37 of the wire clasper 30 to the tips of the clamping arms 31 corresponds to a
length substantially similar to the length L_h from the flange 14 of the ultrasonic horn 10 fixed to
the tip 21 of the bonding arm 20 to the positive side end of the horn main body 11 in the Y
direction. For this reason, a resonant frequency f_2 of the ultrasonic horn 10 in the X direction
10 becomes a frequency close to the resonant frequency f_1 of the clamping arms 31 in the X
direction. For this reason, due to resonant vibration of the clamping arms 31 in the X direction
transferred from the bonding arm 20, the ultrasonic horn 10 resonates in the X direction as
indicated by the arrow 96 in Fig. 6A, and a tip of the horn main body 11 laterally vibrates in the
X direction. Accordingly, the capillary 41 attached to the tip of the horn main body 11 vibrates
15 in the X direction.

[0036]

On the other hand, the bonding control unit 62 applies a predetermined voltage to the
ultrasonic vibrator 16 of the ultrasonic horn 10 and causes the ultrasonic vibrator 16 to perform
ultrasonic vibration. Ultrasonic resonance in the Y direction is generated in the horn main body
20 11. Accordingly, as indicated by the arrow 92 in Fig. 5B, the tip of the capillary 41 vibrates in
the Y direction.

[0037]

In this manner, the clasper control unit 61 causes the ultrasonic horn 10 and the tip of
the capillary 41 to vibrate in the X direction by causing the clamping arms 31 to vibrate, and the
25 bonding control unit 62 causes the tip of the capillary 41 to vibrate in the Y direction by driving

the ultrasonic vibrator 16. In this manner, in a state in which the tip of the capillary 41 has vibrated in the XY direction, the bonding control unit 62 operates the Z-direction motor 27 to press the capillary 41 to an electrode of the semiconductor element 53, thereby bonding the free air ball 50 to the electrode of the semiconductor element 53 as indicated by the arrow 91 in Fig. 5B.

[0038]

After bonding to the semiconductor element 53 ends, the bonding control unit 62 operates the Z-direction motor 27 to raise the capillary 41. In addition, the clamper control unit 61 sets the applied voltage V of the actuator 34 to zero and causes the clamping arms 31 to clamp the wire 45. Further, the bonding control unit 62 operates the Z-direction motor 27 and the XY driving mechanism 29 for looping of the tip of the capillary 41, thereby guiding it to a portion on the electrode of the substrate 52 as the arrow 93 illustrated in Fig. 5C.

[0039]

Here, similar to when bonding of the free air ball 50 is performed, the clamper control unit 61 performs vibrations having the applied voltage V of the actuator 34 of the wire clamper 30 at the frequency f_0 close to the resonant frequency f_1 of vibrations of the clamping arms 31 in the X direction. Accordingly, as indicated by the arrow 96 in Fig. 6B, the clamping arms 31 laterally vibrate in the X direction centering on the elastic hinge 37 due to resonance. In addition, as indicated by the arrow 96 in Fig. 6A, the tip of the horn main body 11 laterally vibrates in the X direction, and the tip of the capillary 41 vibrates in the X direction. In addition, the bonding control unit 62 causes the tip of the capillary 41 to vibrate in the Y direction by driving the ultrasonic vibrator 16 as indicated by the arrow 95 in Fig. 5C. Further, in a state in which the tip of the capillary 41 has vibrated in the XY direction, the bonding control unit 62 drives the Z-direction motor 27 to press the tip of the capillary 41 to the electrode

of the substrate 52, thereby bonding the wire 45 to the electrode of the substrate 52 as indicated by the arrow 94 in Fig. 5C.

[0040]

In the wire bonding apparatus 100 which has been described above, the length L_c from the elastic hinge 37 of the wire clasper 30 to the tips of the clamping arms 31 and the length L_h from the flange 14 of the ultrasonic horn 10 to the positive side end of the horn main body 11 in the Y direction correspond to lengths which are substantially similar to each other. For this reason, the resonant frequency f_1 of the clamping arms 31 in the X direction and the resonant frequency f_2 of the ultrasonic horn 10 in the X direction have the number of vibrations similar to each other. According to this constitution, the tip of the capillary 41 can be caused to vibrate in the X direction by causing the ultrasonic horn 10 to perform resonant vibration in the X direction due to resonant vibration of the clamping arms 31 in the X direction. In addition, the tip of the capillary 41 can be caused to vibrate in the Y direction by causing the ultrasonic vibrator 16 to resonate the horn main body 11 of the ultrasonic horn 10 in the Y direction. For this reason, in a state in which the tip of the capillary 41 is caused to vibrate in the XY direction, the wire 45 can be bonded to the electrode of the semiconductor element 53 or the electrode of the substrate 52. Accordingly, a situation in which the shape of a joint portion of the wire 45 exhibits a deformed shape extending in the Y direction and leads to poor joining can be curbed, and thus the bonding quality can be improved. In addition, joint strength between the wire 45 and the electrode of the semiconductor element 53 or the electrode of the substrate 52 can be enhanced.

[0041]

If the tip of the capillary 41 can be caused to vibrate in the X direction by causing the ultrasonic horn 10 to perform resonant vibration in the X direction due to resonant vibration of the clamping arms 31 in the X direction, the length L_c and the length L_h may not correspond to

lengths which are substantially similar to each other, and the length L_c may be within a range of 80% to 120% of the length L_h , for example.

[0042]

In addition, since the resonant frequency f_1 of the clamping arms 31 in the X direction
5 and the resonant frequency f_2 of the ultrasonic horn 10 in the X direction are high frequencies
near 2 kHz, for example, the tip of the capillary 41 can be caused to vibrate in the X direction at
a high frequency, and the number of vibrations at the tip of the capillary 41 in the X direction
during bonding can be increased even when bonding is performed within a short period of time.
Accordingly, quality of bonding can be improved.

10 [0043]

Moreover, the clamping arms 31 can be caused to vibrate in the X direction while the
wire clasper 30 is reliably maintained in an open state by setting the base voltage V_B to a
voltage within a range of 80% to 100% of the open voltage V_0 and setting the voltage range ΔV
to a voltage within a range of 8% to 30% of the open voltage V_0 . Accordingly, a situation in
15 which the clamping arms 31 touch the wire 45 during vibrations and vibrations in the X
direction are disturbed can be curbed, and thus the bonding quality can be improved.

[0044]

In addition, in the wire bonding apparatus 100 of the embodiment which has been
described above, a situation in which bonding is performed by causing the tip of the capillary 41
20 to vibrate in the XY direction has been described, but it is not limited thereto. The tip of the
capillary 41 may be caused to vibrate in only the X direction to perform bonding by causing only
the clamping arms 31 to vibrate in the X direction without driving the ultrasonic vibrator 16. In
this case as well, in the wire bonding apparatus 100 of the embodiment, since the tip of the
capillary 41 can be caused to vibrate in the X direction at a high frequency, the number of

vibrations of the capillary 41 can be increased even when bonding is performed within a short period of time, and thus the bonding quality can be maintained.

[0045]

5 In addition, depending on the thickness of the wire 45 or bonding conditions, when the free air ball 50 is bonded to the electrode of the semiconductor element 53, the tip of the capillary 41 may be caused to perform ultrasonic vibration in the Y direction by driving only the ultrasonic vibrator 16 without causing the clamping arms 31 to vibrate in the X direction, and when the wire 45 is bonded to the electrode of the substrate 52, the tip of the capillary 41 may be caused to vibrate in the X direction by causing only the clamping arms 31 to vibrate in the X
10 direction without driving the ultrasonic vibrator 16. Accordingly, collapse of a compression ball during bonding can be curbed, and thus the bonding quality can be improved.

[0046]

In addition, in the wire bonding apparatus 100 which has been described above, the ultrasonic horn 10 has been described such that the flange 14 of the horn main body 11 on the
15 proximal side is attached to the tip of the bonding arm 20, but it is not limited thereto. A portion other than the proximal part of the horn main body 11 may be constituted so as to be attached to a central part or a portion near the tip of the bonding arm 20.

[Reference Signs List]

[0047]

20 10 Ultrasonic horn
11 Horn main body
12 Base part
13, 33 Opening
14 Flange

	15, 18, 25, 35 Bolt
	16 Ultrasonic vibrator
	17 Piezoelectric element
	20 Bonding arm
5	21 Tip (positive side end in Y direction)
	24 Seat
	26 Rotation center
	27 Z-direction motor
	28 Base
10	29 XY driving mechanism
	30 Wire clasper
	31 Clamping arms
	32 Base body part
	34 Actuator
15	36 Arm attachment part
	37 Elastic hinge
	38 Recessed part
	41 Capillary
	45 Wire
20	50 Free air ball
	51 Bonding stage
	52 Substrate
	53 Semiconductor element
	60 Control unit

61 Clamper control unit

62 Bonding control unit

100 Wire bonding apparatus

[CLAIMS]

[Claim 1]

A wire bonding apparatus that includes an ultrasonic horn in which a bonding tool having a wire inserted therethrough is attached to a tip thereof and a bonding arm to which the ultrasonic horn is attached and which performs bonding of the wire to a bonding target by bringing the bonding tool into contact with or separating the bonding tool from the bonding target, the wire bonding apparatus further comprising:

a wire clamber that has clamping arms protruding in a longitudinal direction from the bonding arm and clamping the wire, and a base body part attached to an upper side of the bonding arm and accommodating an actuator for performing an opening/closing operation of the clamping arms; and

a control unit that adjusts the opening/closing operation of the actuator of the wire clamber,

wherein the control unit causes the clamping arms to vibrate in an opening/closing direction in an open state using the actuator of the wire clamber during bonding.

[Claim 2]

The wire bonding apparatus according to claim 1,

wherein the control unit drives the clamping arms in the opening/closing direction at a frequency within a range of 80% to 120% of a resonant frequency of the clamping arms using the actuator of the wire clamber during bonding.

[Claim 3]

The wire bonding apparatus according to claim 1,

wherein lengths of the clamping arms of the wire clamber correspond to a length within a range of 80% to 120% of a length of the ultrasonic horn.

[Claim 4]

The wire bonding apparatus according to claim 2,
wherein lengths of the clamping arms of the wire clasper correspond to lengths within
a range of 80% to 120% of a length of the ultrasonic horn.

5 [Claim 5]

The wire bonding apparatus according to any one of claims 1 to 4,
wherein in the wire clasper, the clamping arms are in an open state when a
predetermined open voltage is applied to the actuator and the clamping arms are in a closed state
when no voltage is applied to the actuator, and

10 wherein the control unit causes the clamping arms to vibrate in the opening/closing
direction in an open state by applying a fluctuation voltage fluctuating within a predetermined
voltage range centering on a base voltage that is the same as the predetermined open voltage or
lower than the predetermined open voltage to the actuator.

[Claim 6]

15 The wire bonding apparatus according to claim 5,
wherein the base voltage corresponds to a voltage within a range of 80% to 100% of the
predetermined open voltage, and

wherein the predetermined voltage range includes a voltage within a range of 8% to
30% of the predetermined open voltage.

20 [Claim 7]

The wire bonding apparatus according to any one of claims 1 to 4 further comprising:
an ultrasonic vibrator that causes the ultrasonic horn to perform ultrasonic vibration in
the longitudinal direction,

wherein the control unit adjusts driving of the ultrasonic vibrator, causes the clamping

arms to vibrate in the opening/closing direction in an open state using the actuator of the wire clamper during bonding, and at the same time, causes the ultrasonic horn to perform ultrasonic vibration in the longitudinal direction by causing the ultrasonic vibrator to perform ultrasonic vibration.

5 [Claim 8]

The wire bonding apparatus according to claim 5 comprising:

an ultrasonic vibrator that causes the ultrasonic horn to perform ultrasonic vibration in the longitudinal direction,

10 wherein the control unit adjusts driving of the ultrasonic vibrator, causes the clamping arms to vibrate in the opening/closing direction in an open state using the actuator of the wire clamper during bonding, and causes the ultrasonic horn to perform ultrasonic vibration in the longitudinal direction at the same time by causing the ultrasonic vibrator to perform ultrasonic vibration.

[Claim 9]

15 The wire bonding apparatus according to claim 6 comprising:

an ultrasonic vibrator that causes the ultrasonic horn to perform ultrasonic vibration in the longitudinal direction,

20 wherein the control unit adjusts driving of the ultrasonic vibrator, causes the clamping arms to vibrate in the opening/closing direction in an open state using the actuator of the wire clamper during bonding, and causes the ultrasonic horn to perform ultrasonic vibration in the longitudinal direction at the same time by causing the ultrasonic vibrator to perform ultrasonic vibration.